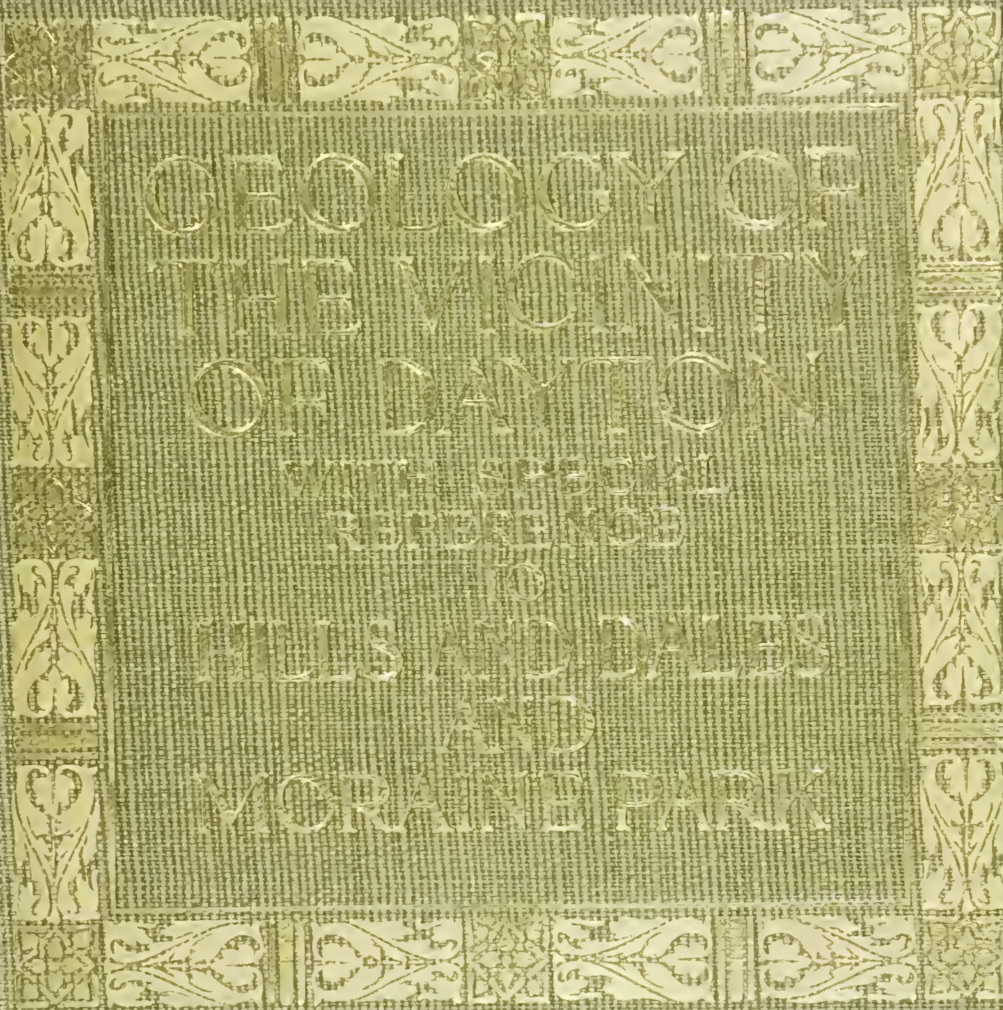

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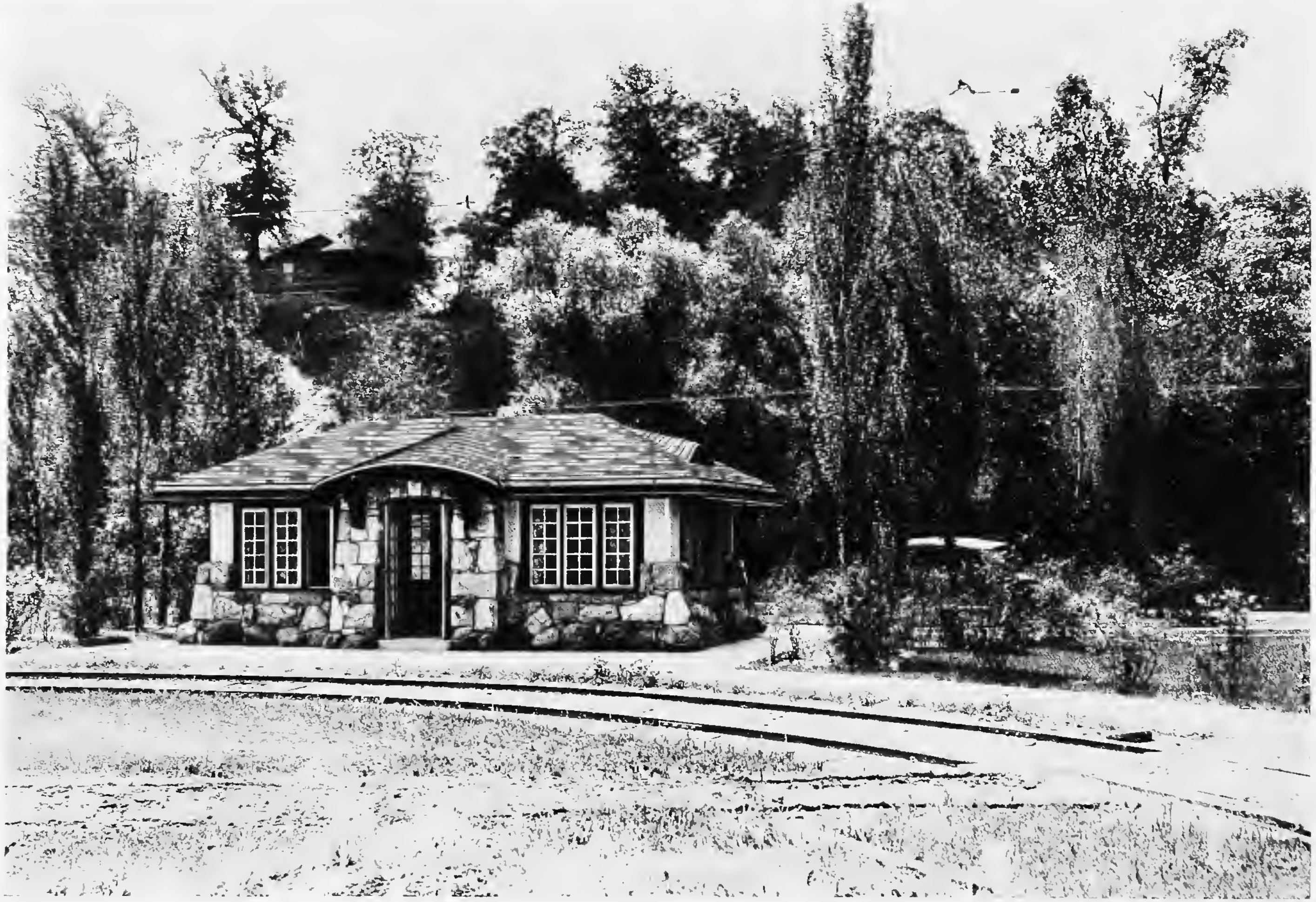

MORAINE PARK STATION, built of boulders of Canadian origin, transported to Ohio by glacial ice. A glimpse of the Deeds cottage, at the northern edge of the Delco Dell grounds, is seen beyond the station

AN INTRODUCTION

TO THE

GEOLOGY OF DAYTON AND VICINITY

With Special Reference to the Gravel Ridge Area
South of the City, Including Hills and
Dales and Moraine Park

By

AUG. F. FOERSTE

NINETEEN HUNDRED FIFTEEN
DAYTON, OHIO

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FOREWORD

FOR many years Prof. Wm. B. Werthner and the writer of the following pages have found pleasure in roaming over the gravel ridge area south of Dayton, studying its geological history and becoming acquainted with its plant and bird life. Many changes have taken place within this time.

In 1877 there was a swamp directly north of the present Schantz plat, northeast of Oakwood, full of fringed gentians, the scarlet lobelia, the shooting star, and a host of other flowers, forming a botanical garden unrivaled in the number and variety of the forms growing within such a narrow area. The blue-eyed Mary and Virginia cowslip flourished in the dense thickets along the Bluffs. The long-spurred violet grew on the northern slopes of the Adirondack ridge in the Hills and Dales area, and in early March the skunk cabbage was found in the marsh at the southern end of the Country Club golf ground.

At that time the walls of the mound-builders' fort in the Calvary cemetery could be followed with ease. The mound at the northern end of the fort had been opened and we heard of the find of a few "Indian relics." East of Alexandersville there was an old farmer, a Mr. Binckley, who was a source of great delight to the boys. He had a most wonderful collection of "Indian relics" and was happy in showing them to all who were interested. He knew where all his relics came from and he told us why the mound-builders must have been quite a different race from the Indians who inhabited this part of Ohio when the first white men arrived. He owned part of the geometrical earthwork located at Alexandersville and persuaded his neighbors who owned the rest to assist him in keeping all of it in good condition.

At that time the various ridges characterizing the area west of the Cincinnati pike could be traced through the cemetery ground as far as the

Bluffs overlooking the canal, and the cemetery had made very little change in the general appearance of the land. Practically no regrading had been done. Each year a sugar camp was started in early spring in the hollow west of the Chapel ridge at the western end of the Nollman farm.

In 1893 Prof. Werthner and the writer began the photographing of the details of the topography shown by the gravel ridges, and two years later a large number of stereopticon slides were prepared in order to interest our pupils and the general public in the glacial history of this territory. A part of these views, taken so long ago by Prof. Werthner, are included among those used for the present publication.

We always hoped that some day this great gravel ridge area might become a public park, but never dreamed of the present park system, including the Hills and Dales and the Moraine Park, by means of which a large part of the territory has been thrown open to the public through the private generosity of Mr. John H. Patterson and Mr. E. A. Deeds. Our happiness would be made complete if only it were possible to save, without further mutilation, the Pike and Chapel ridges west of the Cincinnati pike, which are unrivaled for height, steepness and length in any part of the United States.

It is with pleasure that we have renewed our more detailed studies of the gravel ridge area during the last two or three years. The results are expressed on the following pages. Here the writer has attempted to bring together all of the material likely to be of interest to the local investigator of geologic problems. Here are given the answers to all the numerous questions which others have put to us frequently during our work as teachers in Dayton. Special care has been exerted to give, wherever possible, the line of reasoning which has given rise to the conclusions drawn from the observations made. There is no pretense of originality or of finality in these statements. All geological work is accumulative. Each observer is likely to bring with him a new point of view and hence to contribute differences in solution of the problems investigated. All that is hoped is to give a little impetus toward interesting others in the geological history of our surroundings and to give a little assistance to those who already have had their interest aroused.

Others have worked over the same ground. The large monograph by Frank Leverett, on the Glacial Formations and Drainage Features of the Erie and Ohio Basins, published by the United States Geological Survey, is an authentic discussion of a much wider territory, from which the present writer has drawn freely. Glaciation in Ohio was discussed by Prof. Frank Carney in 1910, in the Bulletin of Denison University. The much shorter article by Earl R. Scheffel on An Esker Group South of Dayton, Ohio, published in this Bulletin in 1908, covers the same territory as the present publication, and presents in few words all the chief characteristics of the gravel ridge area. In 1905, the same writer explained the Origin of the Spring Valley Gorge. The History of the Little Miami River was presented by Prof. J. A. Bownocker, in a paper printed by the Ohio Academy of Science in 1900. For a general discussion of glacial phenomena, without reference to any particular locality, the great American textbook on Geology by Chamberlin and Salisbury, in the Public library, will be found most instructive. All that is attempted in the present publication is to unite within one cover as many as possible of the points of local interest and to show their local application.

The territory selected for special discussion includes all of the gravel ridge area south of Dayton, extending from Oakwood, Carrmonte and the Calvary cemetery southward through Hills and Dales, and the Moraine Park grounds to the southern end of the ridge area at Hole's creek. This is one of the most interesting areas of glacial stream action in the United States and as such is of peculiar interest to those who live in its vicinity.

This volume was begun in response to the request of Mr. E. A. Deeds that a few pages of printed matter be produced, describing the chief points of geologic interest in Moraine Park, his beautiful estate among the hills south of the city. Soon, however, it was found desirable to include also illustrations from Hills and Dales, and from the gravel ridge area south of the Calvary cemetery, and so the few pages grew into a pamphlet. Through the generosity of Mr. Deeds, numerous photographs were added, a map of the gravel ridge area was prepared and investigations were extended to other points beyond the limits of the gravel ridge area, until the pamphlet grew into the present volume.

Finally, Mr. Deeds assumed the entire expense of publication. Thus it became possible to produce a richly illustrated volume which, although centering its interest in the immediately surrounding territory, extends its interest beyond these limits and includes a partial discussion of a much more extended territory.

December 1, 1915.

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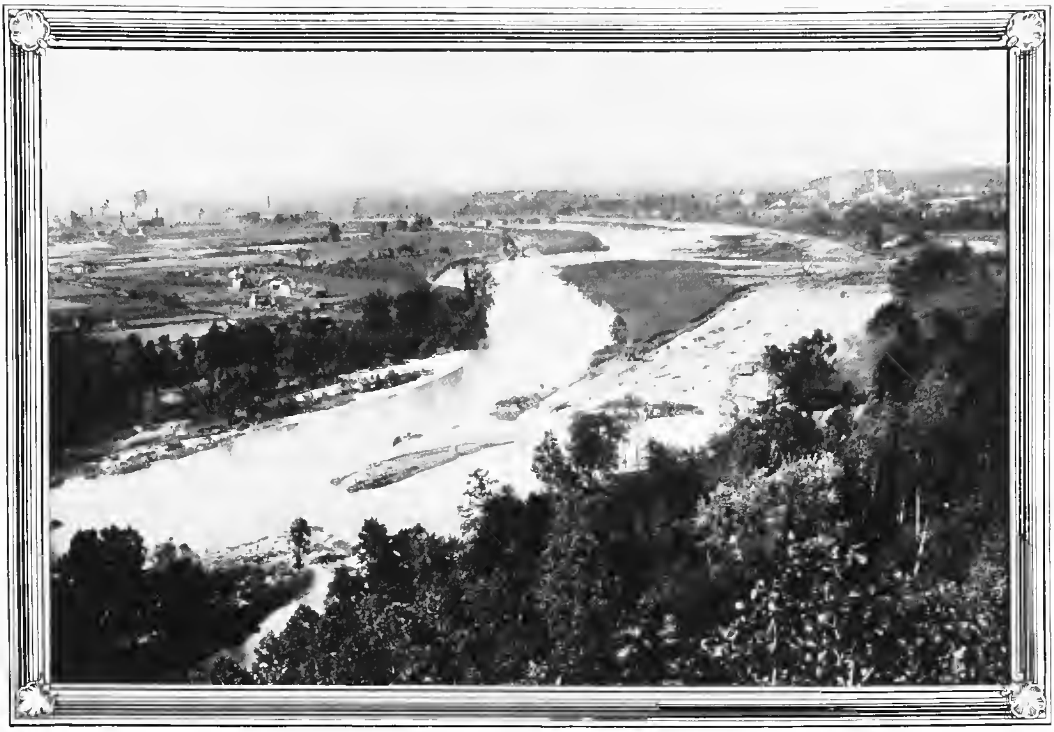
GEOLOGY OF DAYTON AND VICINITY



The Miami river seen from the northern end of the fort in Calvary cemetery. This part of the river channel is to be straightened.

CHAPTER I

THE GRAVEL RIDGES SOUTH OF DAYTON

1. The Charm of Nature

THE charm of trees, underbrush, and wild flowers, the singing of birds and the activity of the insect world, the rippling of the brook, the wavering of autumn foliage and the changes of sunset colors, glimpses of deep valleys and vistas across flat fields to the hills beyond, all these may be enjoyed in any rugged country more or less covered with woodland. The varying aspect of bark and branches of the denuded trees, the shades of brown and yellow of the fallen leaves, scurrying before the wind, the drifts of snow and the pendant icicles, all invite the wayfarer, both under sunny skies and gray, even during the wintry months of the year. Nature is lavish in her display and ever varying in her moods, from the first peep of the early white bloodroot from beneath the blackened soil to the last glow of the goldenrod amid the purple asters along the country lane.

2. *Law and Order in Nature*

Amid all this profusion of life and color there is order and law. Nature is organized into groups and societies. The plants of the beech woods are not those of the maple grove. The open forest and the dense thicket shelter different flowers. The margin of the pond and the deeper waters have different floras. Each of these situations harbors a different insect life and invites a different group of birds and four-footed animals.

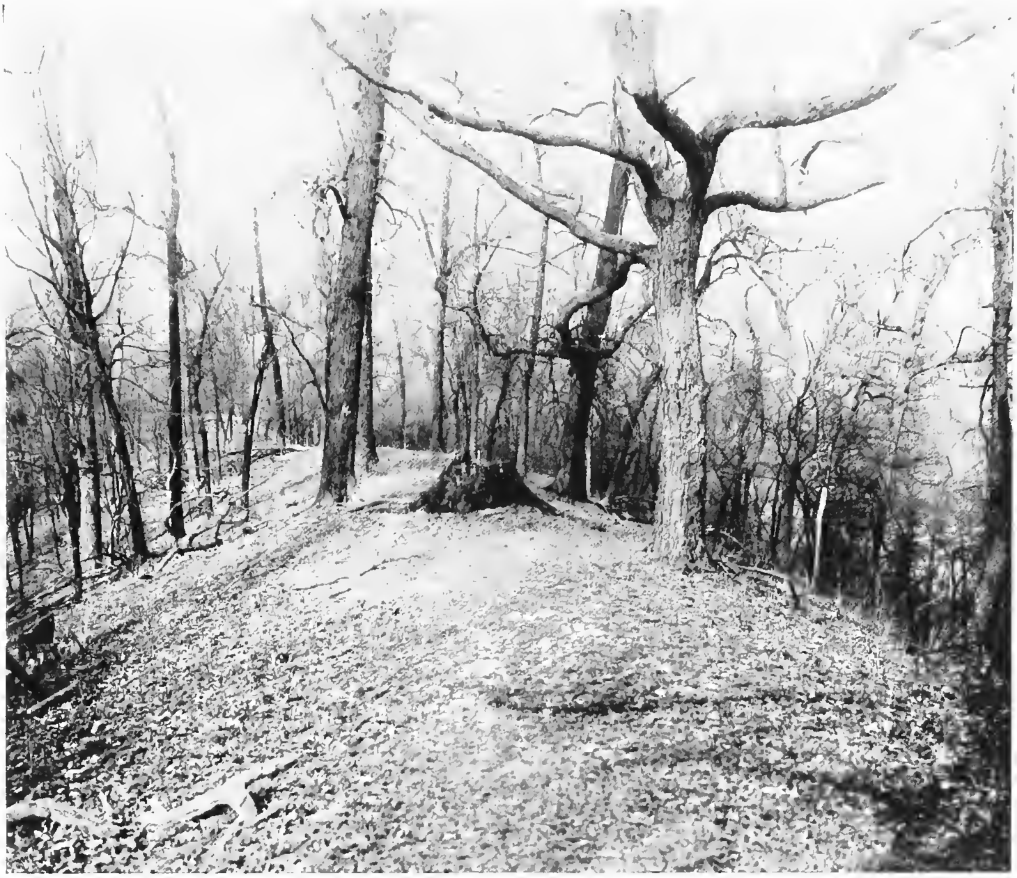
3. *Hills and Valleys as Records of Geological History*

Nature differs even in her forms of hills and valleys. The Hills and Dales that extend south of Dayton, from Carrmonte and Calvary Cemetery to Moraine Park, differ from the hills and valleys near the Soldiers' Home, or near Huffman hill, or along the Stillwater, or along the Great Miami. Each hill and each valley is a record of the history of that section of the earth of which it forms a part. Wherever the history has been different, the form of hill and valley differs correspondingly.

This is what lends interest to the study of the topography of a country —of the varying shapes of hills and valleys, of streams and lakes; how they came to exist, and how they came to assume the forms and structures they now possess. A stroll through the woods and down the glen reveals to the eyes of the geologist the history not of wars nor of the deeds of former races of men, but of ages long preceding the advent of man, and of animals long extinct.

4. *Introduction to Hills and Dales Topography. See map inserted at back of book*

As an introduction to the topography which is characteristic of the territory south of Dayton, let us take a Hills and Dales car to the point, about a mile south of Carrmonte, where this car line turns off eastward from the Cincinnati pike. Here the westward extension of the O'Neil road



View of the Pike ridge, looking northward from a point a short distance north of the O'Neil road. Notice the top of the ridge, too narrow for two wagons to pass.

crosses a narrow gravel ridge, called the Pike ridge, by means of a deep cut. A short but steep climb from the farther end of the cut is necessary to reach the top of the ridge.

The chief features are in evidence at once. The ridge is remarkable for its height, its narrowness, its comparative straightness, and its length; and, although far above stream level, it has been built up altogether from gravel and sand.

At the O'Neil road cut, the top of the ridge is 100 feet above the low ground along the Cincinnati pike on the east, and 95 feet above the wet weather pond in the deep hollow on the west, north of the O'Neil road. The area along the top of the ridge usually does not exceed 25 or 30 feet in width. The slope on each side is steep, often equalling 30 degrees in the steeper places. If these numbers do not impress you, then judge the steepness of the hill by climbing it, without using the road.

Such a steep slope is possible only on hillsides built up of solid rock or of coarse gravel. Sand and clay consist of smaller particles and usually give rise to lower gradients. Every builder of railroads knows that finer materials tend to spread out more, laterally, and that every kind of loose material has a maximum slope above which it does not tend to remain at rest. Broken stone will build up steeper slopes than rounded pebbles.

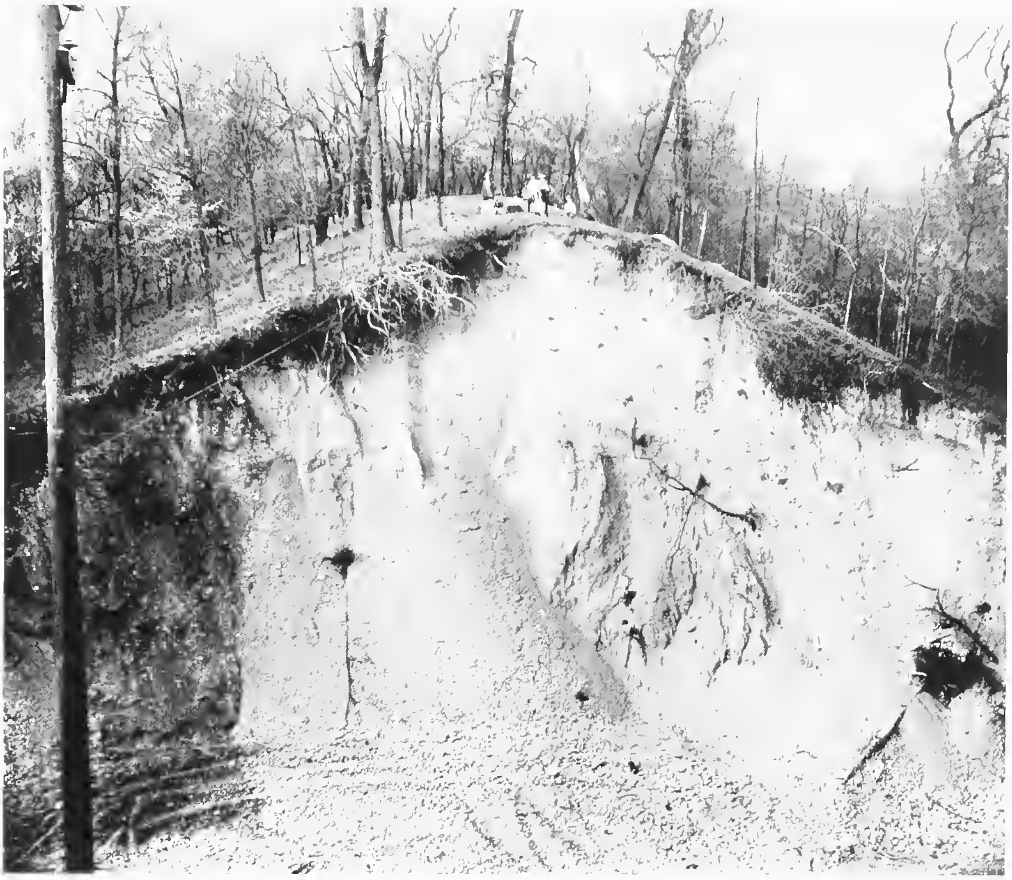
The ridge here consists chiefly of gravel. This can be seen by looking down into the cut, by means of which we have ascended the ridge, but the same fact might be inferred from the abundance of the pebbles along the crest of the ridge, and also along its sides where the latter are not covered deeply by soil.

5. *The Pike Ridge*

The length and straightness of the Pike ridge can be appreciated best by following it northward. North of the O'Neil road, the trend of the ridge is at first northerly. Then it turns slightly east of north until it reaches one of its higher elevations or peaks, beyond which it returns to its former northerly course. Clumps of red haw and wild rose, with their protecting thorns and prickles, are scattered along the crest. Grape and woodbine spread among the lower branches of the trees. Northward, a fence crosses the ridge, and beyond the fence, the ridge descends rapidly, being crossed by a natural depression or gap, beyond which the ridge continues again.

The Nollman farm lane passes through the gap in a westerly direction. North of the gap there are two ridges, but, of these, the eastern ridge is in more direct alignment with the Pike ridge, which we have been following from the south, and is regarded as an extension of the latter. Northward this eastern ridge becomes distinctly hummocky, but a glance down the valley, between this eastern or Pike ridge and the western or Nollman ridge, will reveal the ridge-like character of the succession of hummocks bordering the western side of the Cincinnati pike.

The Pike ridge terminates northward at a point east of the home of Mr. Sauerman, opposite the western end of East Woodburn Avenue.



The Pike ridge at the O'Neil road cut, looking north. Note the narrowness of the top of the ridge.

The total length of the Pike ridge, north of the O'Neil cut, is almost a mile, and its direction along this entire length is approximately north and south. About 10 degrees east of north would be a fair average for its general trend.

Only that part which is between the O'Neil road and the Nollman road is readily accessible, but this is also the most interesting part of the ridge, on account of its conspicuous elevation and narrowness.

6. *The Chapel Ridge*

West of the Pike ridge is an equally steep ridge, extending farther north. It may be reached by following the Nollman lane westward, across a shallow part of the intervening Nollman hollow, to the top of the Chapel ridge, at a point southwest of the pond occupying the lowest part of this hollow. This is another ridge remarkable for its height, its narrowness, its comparative straightness, and its length.

The highest knob, along the Chapel ridge, south of the Nollman road, is 65 feet above the low ground on both sides of the ridge. About a sixth of a mile north of the Nollman lane there is another of the more conspicuous elevations along the crest of the Chapel ridge, which is 70 feet above the Nollman pond, east of the ridge, and 110 feet above the pond in the Sugar Camp hollow, on the western side of the ridge.

The view from this part of the Chapel ridge is superb. Deep valleys border it on both sides, and vistas of the more distant country, westward, are seen among the trees. It is interesting especially in winter or in early spring, when the leaves have fallen from the trees. For those who like roughing it, snow lends an additional charm. It outlines more clearly the distant hills and gives relief in sunshine and shadow. Along the crest of the ridge the walking usually is fair. Westerly winds drive most of the snow from the path. It clings to the eastern margin of the crest and lies deep on the slopes beneath. The velvet green of the mullein leaf peeps from beneath the snow. Some of the grass still is green, and projecting dry stalks and leaves of last year's plants relieve the mantle of white from any feeling of monotony.

About two-fifths of a mile north of the Nollman lane the Chapel ridge is interrupted by a natural wide depression or gap, about 25 feet deep, through which the Sugar Camp lane passes in a southwesterly direction. The lane ends at a pond, dry excepting in wet weather. The old sugar camp lay in the woods north of the pond. Here the sap of the maple was collected formerly in earthenware crocks, and boiled down in large open kettles into maple syrup.

North of the Sugar Camp lane the crest of the Chapel ridge rises 90 feet above that part of the valley which lies directly westward, and 100 feet above the lowest ground in the valley eastward. A short distance northward the ridge is crossed by a wire fence. So far, the woods along the ridge have been open, and the walking agreeable, with pleasant views on both

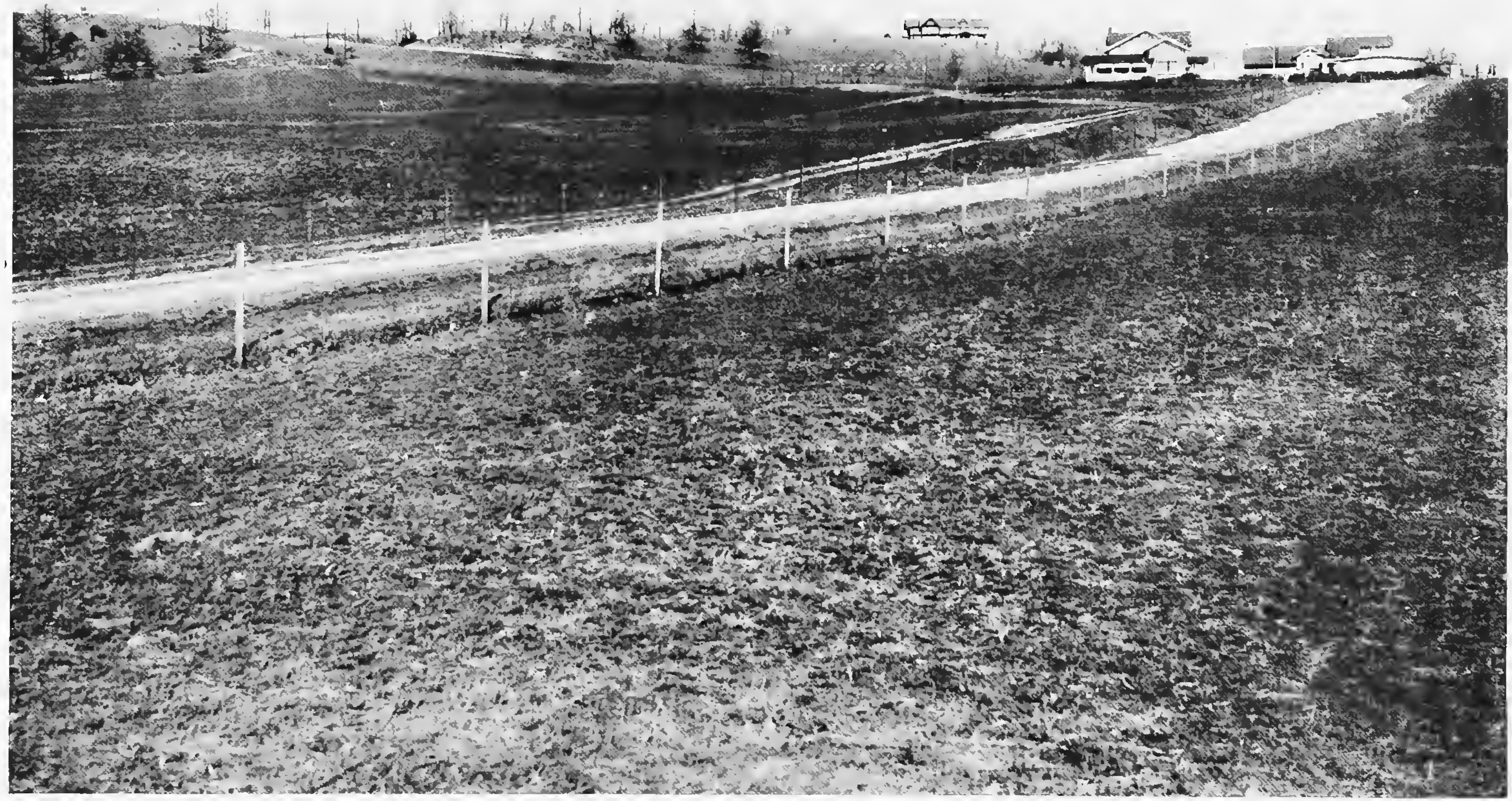
View of the west side of the northern end of the Chapel ridge, with the buildings at the entrance to Calvary cemetery on the right. Photograph taken twenty years ago.

sides of the ridge. North of the wire fence, however, the crest of the ridge is covered with a thicket of red-buds. This is a part well worth visiting in spring, when the red-buds are in full flower. Later in the season they obstruct the view, but a short walk northwestward, down the slope of the ridge, brings us to the lane following the western side of the Chapel ridge northward to the western end of Mayo Avenue.

At the western end of Mayo Avenue, the Chapel ridge formerly was interrupted by another depression or gap, only about 13 feet deep, but a recent cut has increased the depth of this gap to about 25 feet below the level of the immediately adjacent part of the ridge, at the same time giving an excellent exposure of the coarse gravel characterizing the upper part of the material forming the ridge, along almost its entire length.

North of Mayo Avenue, the Chapel ridge rises strongly until it attains a height of 125 feet above the valley eastward. The valley on its western side is much more shallow, scarcely equalling more than 35 feet in depth.

At present the Chapel ridge ends abruptly, at the gravel pit southeast of the chapel in Calvary Cemetery. Formerly it extended farther north-



VIEW of the southern end of the Sunset ridge, showing the Stroop road, the Moraine farm buildings, and a part of Ridgeleigh Terrace ward, to the edge of the bluffs facing the river, but this part was removed in order to improve the appearance of the approaches to the cemetery grounds.

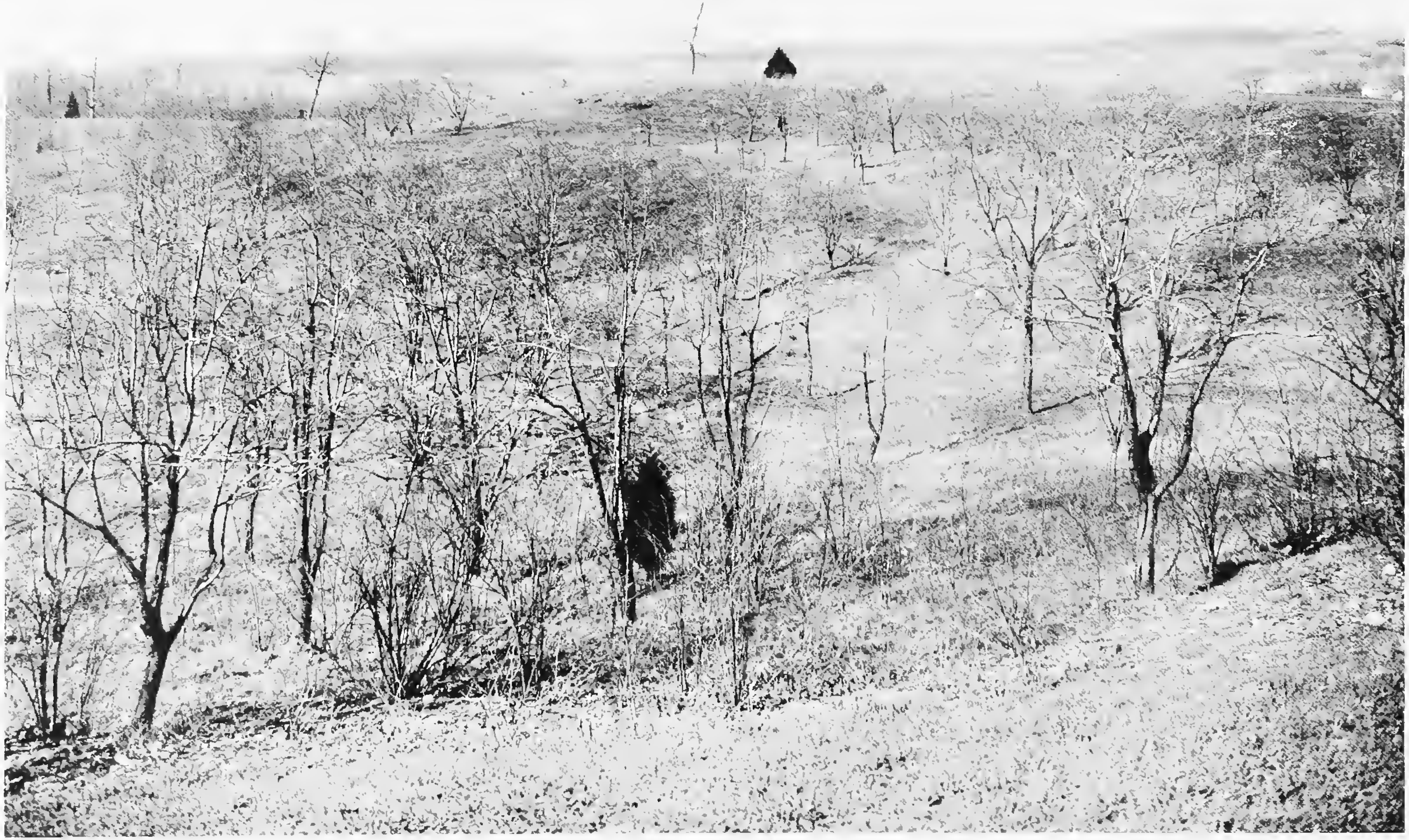
This Chapel ridge is over a mile in length. Its course is practically parallel to the Pike ridge. Its crest is equally narrow and its sides are equally steep. Additional narrow north and south trending ridges traverse the territory farther westward.

Few people know of these remarkably narrow, steep, and straight ridges west of the Cincinnati pike, but they are of especial interest on account of the simplicity of their structure. For long distances, the valleys on both sides of these ridges are uninterrupted by cross ridges, so that the visitor need not be in doubt whether he is following the continuation of the same ridge or not. The topography here consists essentially of long narrow ridges, separated by long and comparatively uninterrupted intermediate valleys.

At some other localities, the long ridges are connected at irregular intervals by transverse ridges, breaking up the long intermediate valleys into a succession of shorter intermediate small hollows, often without any drainage outlet. This modification of the simple ridge and valley structure is well shown on Moraine farm and in the Delco Dell area, a mile south of the O'Neil road.

7. *The Moraine Farm Ridges*

The Moraine farm ridges may be regarded as merely a southward continuation of those which line the western side of the Cincinnati pike, farther northward. South of the O'Neil road cut, the Pike ridge curves southeastward toward the northern part of the long gravel pit, which is exposed southwest of the Power Sub-station, on the western side of the Cincinnati pike. The ridge formerly extended beyond the present location of the Ohio Electric railroad and was connected with the high ridge directly east of the Cincinnati pike, which also is deeply indented at present by a gravel pit, at its northwestern end. A broad, deep, natural depression or gap formerly separated that part of the ridge which is west of the Cincinnati pike from the adjacent part on the east. This gap determined the location of the pike,



VIEW across Old Orchard hollow, looking westward. Eastview ridge forms the farther side of the hollow and the hills of the Highlands are seen beyond when it was first constructed, many years ago, but the two gravel pits and other changes along the intervening pike have removed all traces of the former natural gap.

The top of the ridge at the gravel pit east of the pike is 70 feet above the lowland along the pike westward. It is abruptly terminated southward by the small stream traversing the Governor Cox farm, but standing on the top of the ridge and looking directly across the valley of this stream, we face the gravel pit at the north end of the long Eastview ridge. The latter may be traced for nearly four-fifths of a mile, in a southeasterly direction, to the home of Mr. Kettering, on Ridgeleigh Terrace. Along most of this distance this ridge also is remarkable for its height, its narrowness, its comparative straightness, and its length; moreover, it also is composed entirely of gravel and sand, as were the long narrow ridges west of the Cincinnati pike, north of the O'Neil road cut.

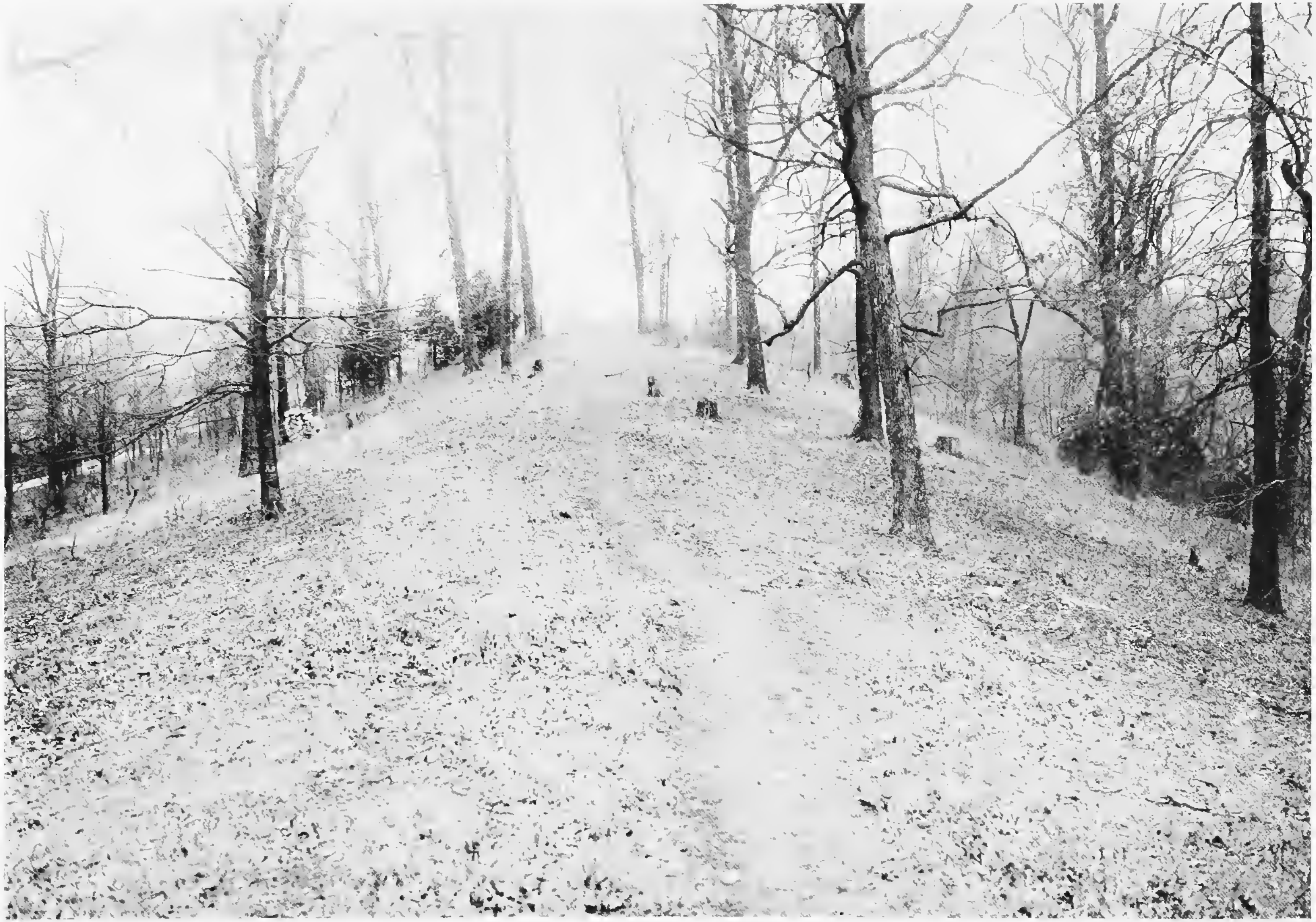
In one respect, however, the ridges south of the O'Neil road cut differ from their northward continuations: they have a different direction. Instead of having an approximately north and south direction, they take a course about 30 degrees east of south.

Essentially the same direction as the Eastview ridge is shown by the Sunset ridge, which extends from Lookout Point, at the southern edge of the Cox farm, past Big Hill knob and the Summer Camp on Moraine farm to a point west of Ridgeleigh Terrace.

One of the interesting features of these gravel ridges east of the Cincinnati pike is the frequency with which they attain a height of 70 to 90 feet above the immediately adjacent lowlands, and the rarity with which they exceed an elevation of 100 feet. This provides frequent outlooks from the crest of the ridges eastward across the broad Locust farm valley, and westward over the wide flat country sloping gently toward the Miami river.

To the student of topography, however, a much more interesting feature connected with these long gravel ridges is the presence of the numerous hollows or dells which they inclose.

One of these, the Old Orchard hollow, east of the Summer Camp, on the Moraine farm, occupies a considerable part of the space between the Sunset and Eastview ridges, and here the ridges rise 25 to 45 feet above



DAVID ridge, looking southward; seen from a point a short distance south of the entrance to the Delco Dell grounds. Sleepy hollow is on the right. A glimpse of the David road is seen on the left the bottom of the hollow, being connected southwards by the high transverse ridge culminating at Tip Top knob. This knob is 100 feet above the level of the Stroop road at the end of the Delco Dell branch of the Hills and Dales car line. Northward, the Old Orchard hollow is closed by the transverse ridge traversed by the northern end of the Big Hill road. Here the lowest part of the transverse ridge is about 20 feet above the lowest part of the Old Orchard hollow, and a similar low spot is found along the Eastview ridge, where it is followed by the Big Hill road, several hundred yards northwest of its junction with the Deeds road. In other words, the bottom of the Old Orchard hollow lies about 20 feet below the lowest part of the enclosing land. Hence there is no direct drainage outlet, and all rainfall must find an exit by sinking into the ground. Since all of this ridge land is made up of loose gravel and sand, very little water remains in the hollow excepting for a short time after a heavy rain.

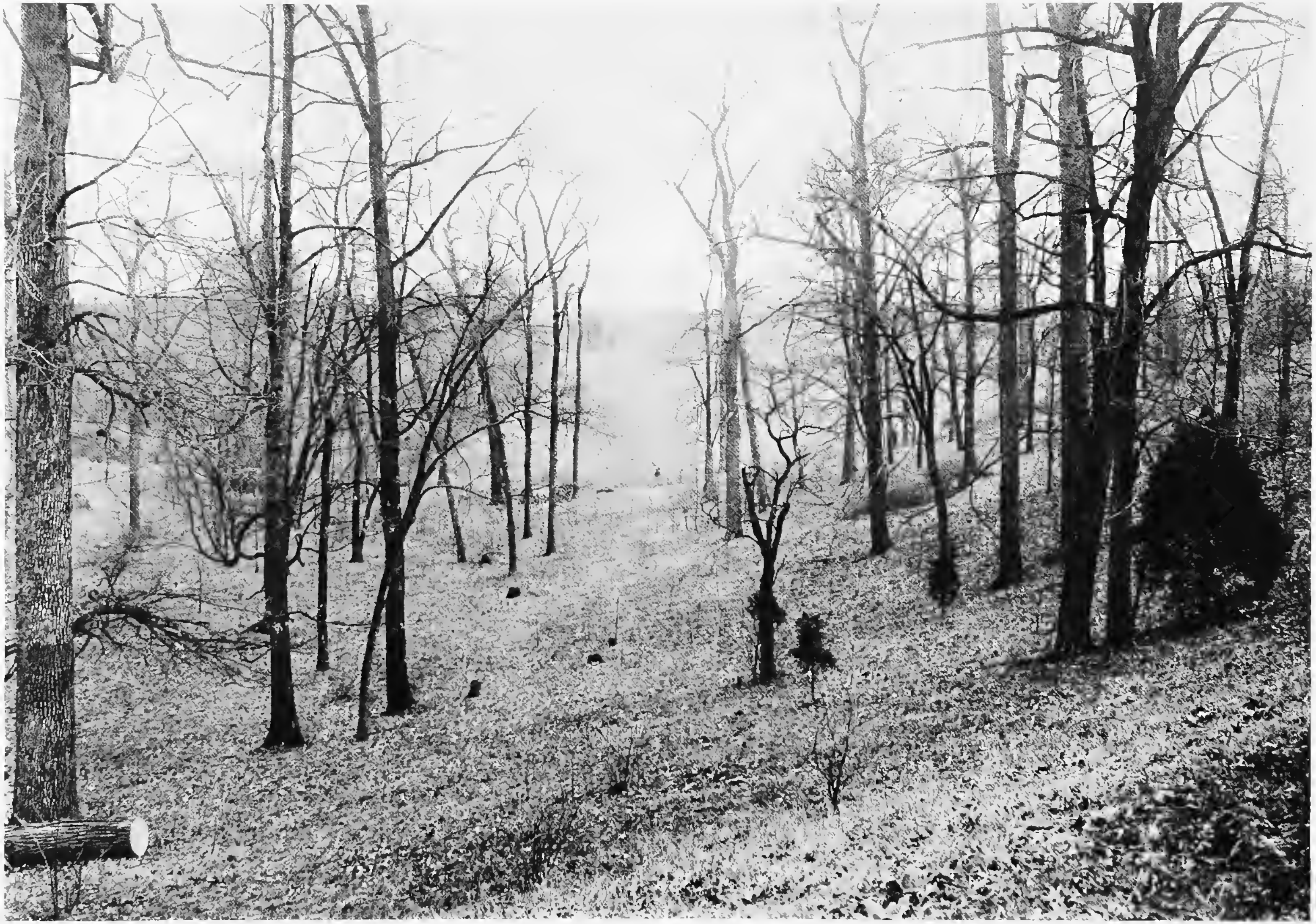
East of the bridle path leading along Sunset ridge from the Summer Camp of Moraine farm to the big bend at the southern end of the Big Hill road, there is another long and narrow hollow, the Sunset hollow. the lowest exits from which, in any direction, lie about 18 feet above the bottom of the hollow. One of these exits is used by the bridle path traversing the hollow in a southeasterly direction. Another low point is found on the Sunset ridge, almost directly opposite the first.

A third hollow, the lowest exit from which lies only about 8 feet above the bottom, virtually is a northwestern continuation of the Old Orchard hollow, but is cut off from the latter by the short transverse ridge traversed by the northern bend of the Big Hill road. It lies along the southern margin of the Governor Cox farm.

A fourth hollow, also small, lies east of the northern end of the Old Orchard hollow, and is separated from the latter by a ridge only 9 feet high at its lowest point. On the eastern side, however, the lowest outlet across the bordering ridge is 13 feet above the bottom of the hollow.

8. The Delco Dell Ridges

The southern termination of the two prominent Moraine farm ridges, near the old school house north of the Stroop road, is as abrupt as the break



VIEW across Sleepy hollow, in the Delco Dell grounds, looking south. The elevated land dimly seen in the distance is the David ridge on the southeast side of the hollow. Part of the Delco ridge is seen in the immediate foreground, on the right. The open ground in the lower part of the hollow is cultivated land north of the stream on the Governor Cox farm. However, the map will indicate that the Delco Dell ridges, notwithstanding this interruption, virtually are direct continuations of the more northern ridges. The Delco Dell grounds include both dells and ridges and are so named on account of being the summer residence of a number of the Delco organization.

The eastern, or David ridge, continues the southeasterly course of the Moraine farm ridges as far as the main entrance to the Delco Dell grounds, from the side of the David road. From this point the David ridge takes a more southerly direction, and soon curves toward the southwest.

The western, or Delco ridge, takes a southerly course as far as the southern end of the Delco dell or hollow, and then also takes a southwesterly course, finally connecting with the David ridge. The David and Delco ridges also are remarkable for their height, their narrowness, their comparative straightness, and their length. As in the case of the more northern ridges, they are composed almost entirely of gravel and sand.

Delco Dell is the most northern hollow enclosed by the Delco and David ridges. Its lowest outlet lies along its southern margin, where the transverse ridge, followed by the main road, is 20 feet above the lowest part of the hollow.

Sleepy hollow, directly south of Delco Dell, and cut off from the latter only by the transverse ridge followed by the main entrance road, evidently is a continuation of the Delco Dell. In length it almost equals the Old Orchard hollow, on the Moraine farm, and it is equally wide, but it is much more impressive on account of its considerable depth, and the greater height and steepness of the ridges enclosing it. The lowest point in the enclosing ridges lies along the Delco ridge, south of the fence at the southern end of the Delco grounds, where the crest of this ridge is 32 feet above the lowest part of the Sleepy hollow. Another low point of exit is found along the Delco ridge, north of the fence, and a third is located on the David ridge, almost directly east of the first, but these second and third low points are fully 50 feet above the bottom of the hollow. The ease with which the water after a heavy rain finds exit from this hollow by sinking into the gravel is indicated by the presence of the cultivated land along the lower part of the hollow, for many years a fertile corn field.

South of the Sleepy hollow is a third hollow, finding its lowest exit toward the north, 12 feet over the bottom. West of this is a fourth hollow, long and narrow, bordering the western margin of the Delco ridge, and having an exit at its northern end 16 feet above the lowest part of the hollow.

Various additional hollows occur along the hilltops as far southward as the lands overlooking Hole's creek, a distance of at least half a mile, but most of these hollows are comparatively shallow and find outlets 10 feet or less above the bottom. Here, moreover, the ridge topography gradually disappears, being displaced by rolling hills dissected by streams permitting an unchecked drainage.

9. *The Hills and Dales Ridges*

The ridges extending from the bluffs at Calvary cemetery to Moraine farm and Delco Dell have been described in considerable detail for several reasons. They emphasize the combination of decided narrowness and steepness with great length. They call attention to the parallelism of neighboring ridges and to their general southerly trend. Their internal structure is exposed better and at more localities, by means of gravel pits and road cuts, than in the case of any other ridges within this area, south of Dayton. In other words, the facts used in the determination of the origin of these ridges are shown here in more striking fashion than elsewhere.

However, these are not the only impressive examples of long and narrow gravel ridges. The Hills and Dales owe their chief charm to their presence. One of the chief ridges, the Adirondack ridge, extends from the angle in the Cincinnati pike, at Carrmonte, in a southeasterly direction, in a remarkably straight course, as far as Inspiration Point. This is a distance of a mile and a half, along which the crest of the ridge rises and falls, widens and narrows, and yet maintains within narrow limits the same course. Adirondack camp and Round camp occupy conspicuous stations along the crest of this ridge. The views toward the west extend over comparatively flat or gently rolling grounds as far as the ridges west of the Cincinnati pike, first described.

East of this Adirondack ridge is the deep valley followed by the

Meadow Brook road. Farther east is a second conspicuous ridge, the Panorama ridge. This begins east of the golf links, belonging to the Country club, and passes east of the Walnut spring, taking a southeasterly direction, parallel to the Adirondack ridge, as far as Fair Forest. Beyond this point, the ridge merges into the elevated land bordering the Panorama road, taking a more southerly course, until it joins the Adirondack ridge at Inspiration Point. Beyond this point, the ridge merges into the highland extending southward along the Panorama road, east of Locust camp, toward the Frederick farm.

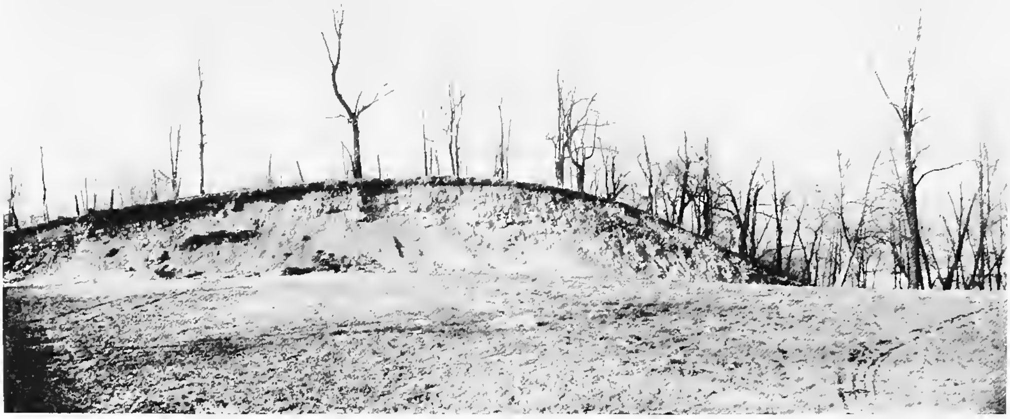
East of Inspiration Point, a rather short ridge extends along the watershed road northward to Overlook Point. Along its northern end there are several small depressions or kettle holes, which are very tiny when compared with the much larger hollows between the long ridges extending from the Calvary cemetery to Moraine farm and Delco Dell.

10. The Ridges and Hollows of Calvary Cemetery

It is evident that the Calvary cemetery topography is identical with that seen among the Moraine farm and Delco Dell ridges. Long, approximately parallel ridges extend in a general north and south direction, and are connected by short transverse ridges, dividing the intervening valleys into short enclosed hollows.

Between the northern end of the Chapel ridge and the western boundary of the cemetery, along the western margin of the bluffs, there are seven ridges, with intermediate hollows, all running in an approximately north and south direction.

The Chapel ridge formerly extended beyond its present termination, at the gravel pit, northward as far as the bluffs, but this part has been removed almost entirely in preparing the approaches for the cemetery. West of the Chapel ridge is the long Lohman ridge, terminating northwest of the chapel in a high knoll. West of the northern end of the Lohman ridge is a ridge terminating northward at the Zitter monument. At the southern margin of the cemetery, this ridge is separated from the Calvary ridge by a deep hollow.



North end of Calvary ridge at the northern limits of Calvary cemetery, looking northward. The flat territory in the foreground occupies that part of the area from which the upper part of the ridge was removed in regrading the cemetery.

The Calvary ridge is the most elevated and conspicuous ridge in the cemetery, the highest part being occupied by the beautiful Calvary monument. Northward this ridge terminates at the mound, on the edge of the bluffs, immediately north of the cemetery grounds. The latter has been opened several times and some "mound-builders" relics have been obtained from it. Recently, the northern part of this ridge has been regraded, exposing large numbers of gravel boulders among the coarse pebbles forming the top part of the ridge. Many of these boulders equalled a foot in diameter, and some exceeded this dimension. Formerly a long transverse ridge extended from a point about a hundred feet south of the Calvary monument diagonally northeastward toward the Zitter monument, already mentioned, at the northern edge of the cemetery. This transverse ridge is the East Fort ridge. Along its crest formerly extended the low earth-wall forming the eastern boundary of the "Mound-builder" fort which occupied a considerable part of the present cemetery grounds, inclosing about twenty-four acres of land.

West of the Calvary ridge is the Gravel Pit ridge. At the northern end of this ridge, immediately north of the cemetery grounds, is the large gravel pit, at present operated by the Dayton Washed Gravel and Sand Company.

The top of this pit is 185 feet above the level of the canal, and the gravel pit itself has a vertical face of 145 feet, the base of the pit being 40 feet above the level of the canal. Southwest of the Calvary monument, the crest of this ridge is traversed by a woodland road which near the entrance to the woods passes through the southern gateway of the "Mound-builder" fort.

West of the northern end of the Gravel Pit ridge there are three ridges, the first of which skirts the eastern edge of the woods on the western side of the cemetery; the second ridge extends southward through the denser parts of these woods; and the third ridge follows the margin on the bluffs on the western side of the cemetery grounds. This third ridge is the one followed by the western part of the low earthwork enclosing the "Mound-builder" fort.

View of the western part of the southern earth wall of the fort in the Calvary cemetery, looking eastward toward the southern gateway, which is at the edge of the woods.

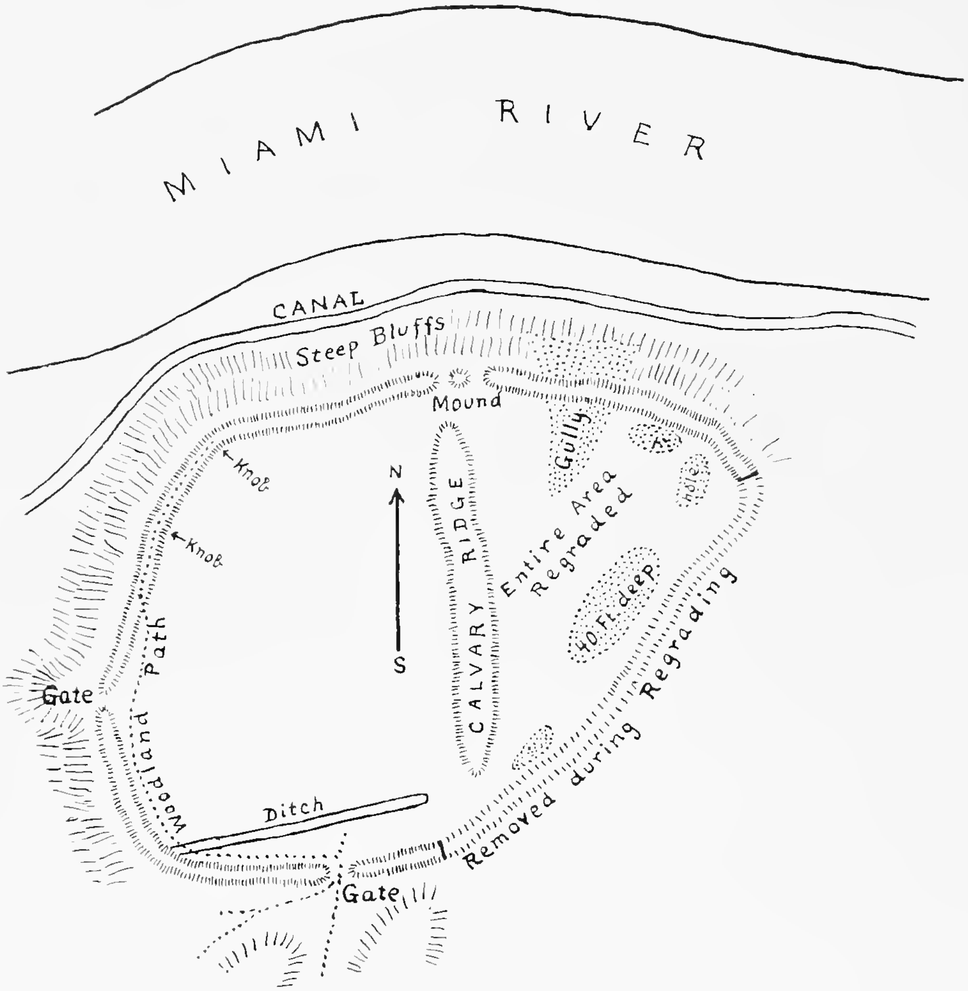
CHAPTER II

THE MOUND-BUILDER FORT IN CALVARY CEMETERY

11. *The Mound-Builder Fort in Calvary Cemetery*

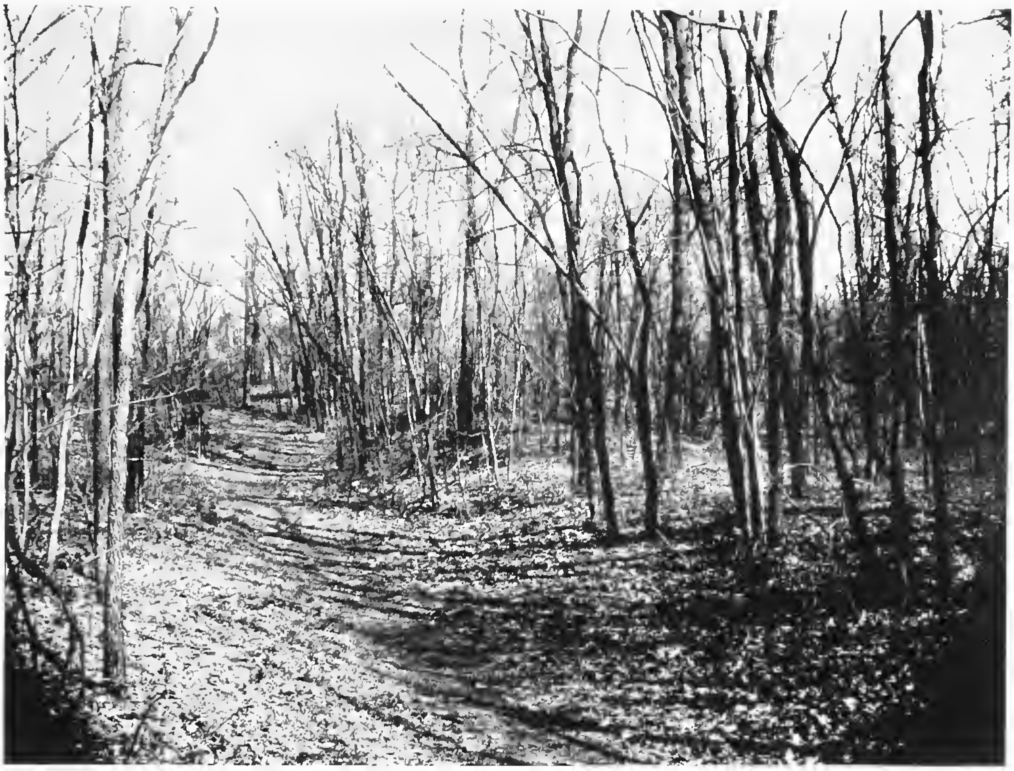
The early races inhabiting this country before the arrival of the white man must have found the deep hollows, surrounded on all sides by ridges, convenient natural refuges when attacked by their enemies. There is abundant evidence that a part of the high land bordering the bluffs, along the northwestern part of the Calvary cemetery, was used for such a purpose. In fact, several hollows here were enclosed by the same earthwork, the low earth embankment forming the walls of the fort taking advantage, as far as possible, of the ridges already present.

At the time of the advent of the white man, the Indians, then inhabiting the country, did not make use of the fort on the bluffs. In fact, they did not use any of the forts found in this part of Ohio, nor did they retain any memory of their use as forts. Moreover, the great age of the trees growing



Ancient earthwork or fort in Calvary cemetery. Map based on survey. Only the western part, from the southern gate to the northern knob, is well preserved. The northern part can scarcely be traced, and the eastern part has been removed entirely by regrading. All of the eastern half of the enclosure, including the Calvary ridge, has been regraded. The depressions noted by the surveyor probably were natural hollows among the network of ridges. Large hollows still exist in their natural condition in the western part of the enclosure and also south of the same. Twenty-four acres of land are estimated to have been included in this fort. Toward the lower part of the gully there formerly was a spring.

on the earth-walls, indicates their neglect for several centuries. Under these circumstances it was natural to ascribe the construction of the earthwork forts in Ohio to another race—the "mound builders." However, it is readily possible that the so-called mound builders were merely early tribes of Indians, with very different customs and with a very different stage of



Same view as on page 37, but taken sufficiently far toward the left to show the slight depression often seen just within the walls of the forts constructed by the mound-builders.

civilization from that attained by the Indians who were in actual possession when this country was first visited by Europeans.

Thirty years ago, the walls of the Calvary cemetery fort could be traced along their entire course. Parts are still preserved. From the mound at the northern end of the Calvary ridge the earth-wall descends the deep gully eastward and ascends the steep hillside on the other side of the gully, but this part of the wall is almost obliterated. Farther eastward, where the wall crosses the head of a much smaller gully, the earth-wall may be distinguished even from a distance. East of this second gully the earth-wall formerly turned rather abruptly southwestward, along the crest of the East Fort ridge, now occupied by the Zitter, Weingartner, Pflaum and Stomps monuments, to a point about 100 feet south of the Calvary monument. Beyond this point it extended in a somewhat more westerly direction as far as the southern gateway to the fort. Only the last 200 feet of this part of the wall is still preserved. All of the east wall has been removed in regrading the cemetery.

The southwestern and western part of the earth-wall surrounding the fort, on the contrary, is very well preserved. From the southern gateway the wall extends westward as far as the bluffs on the western margin of the cemetery grounds. A woodland road follows the northern side of this part of the wall. The southwestern part of the fort was its most vulnerable portion since here several ridges reach the wall, from the south, at about the same level as the wall. One of these ridges leads directly into the fort at its southern gateway, and is used at present by a woodland road. Another ridge lies farther westward, and is reached by the road diverging southwestward from the gateway. There is also high land at the southwestern angle of the fort. Therefore, the entire southwestern line of the fort was still further protected by a long ditch, originally about two or three feet in depth, which still may be traced from a point 120 feet north of the gateway westward to the southwestern angle of the fort. Formerly it extended also eastward, almost as far as the crest of the Calvary ridge.

From the western end of the ditch, at the southwestern angle of the fort, the earth-wall extends northward along the upper edge of the bluffs. At one point it is interrupted by a second gap or gateway, where a small spur projects westward from the margin of the bluff. From this point the earthwork takes a more northeasterly course, as far as the high knob several hundred feet directly west of the northern termination of the Gravel Pit ridge. Along most of this western part of the fort the woodland road follows the eastern margin of the earth-wall, but several hundred feet north of the western gateway the road ascends the wall, and from this point northward it follows the crest of the wall.

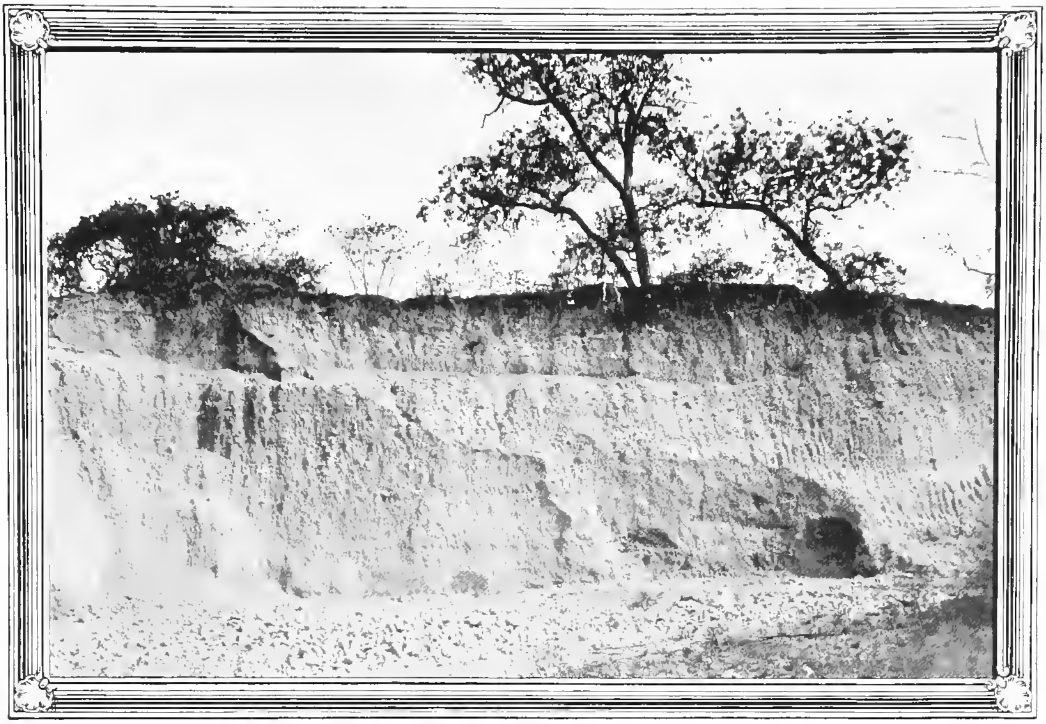
The present height of the earth-wall, along the southern and western margin of the fort, rarely exceeds five feet, and frequently equals only three feet. The original height evidently exceeded five feet, but probably only to a moderate extent.

From the knob at the northwestern edge of the fort the wall followed the northern edge of the bluffs as far as the mound already mentioned, but this part of the wall is but poorly preserved at present.

The entire space included within this earthwork is estimated at 24 acres. It included about eight hollows, of which several were fairly deep. Only those hollows which occurred in the western half of the fort have not been disturbed by regrading.

That this earthwork, notwithstanding its apparently poor adaptability for purposes of defense, was of great value is indicated by the existence of numerous similar earthworks or forts scattered over a wide range of territory in Ohio and neighboring states. It is inconceivable that such laborious work should have been undertaken, unless forts of this type were known to be effective. It is much more probable that, in our ignorance of the type of warfare then prevailing, we fail to realize how well these forts fulfilled their purpose.

It is interesting to note that the earth used in the construction of the Cemetery fort consists of clay, while the surrounding land consists chiefly of gravel with a very thin surface of soil. Apparently the clay used for the fort walls was brought from a distance of at least several hundred yards in baskets. The walls were built up directly on the previously existing land slopes, there being no evidence of any alteration of the previously existing topography beyond the addition of the earth-walls.



Gravel pit at northern end of Chapel ridge, in Calvary cemetery, showing the stratification of the gravels in a direction parallel to the length of the ridge.

CHAPTER III

GRAVEL RIDGES DEPOSITED BY STREAMS

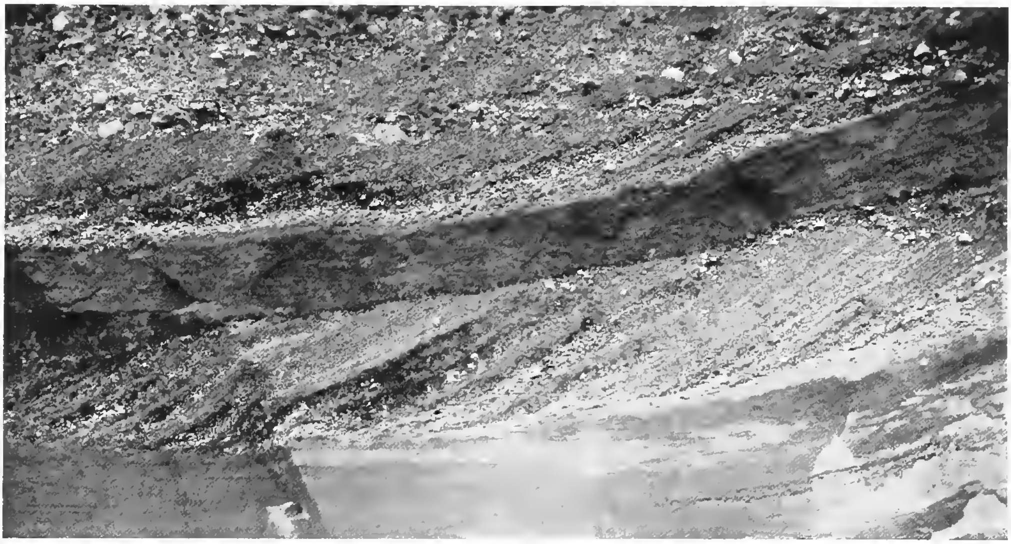
12. *The Origin of Pebbles and Gravel*

In determining the origin of the long parallel ridges south of Dayton the most obvious fact is that all are composed of gravel, in other words, of rounded stones or pebbles. Now, every geologist knows that pebbles are only the rounded fragments of larger rock masses. In their original state rocks may occur as a series of successive layers, more or less interbedded with clay, or as large irregular masses of rock, often continuous over many square miles of territory, but never in the form of rounded pebbles. Any one visiting the large quarry northwest of the railroad station at Centerville, or the much smaller quarries in the vicinity of Dayton, can not fail to be impressed by the occurrence of these rocks in layers, often differing greatly in thickness, but extending laterally over wide areas. Similar facts may be noticed in the big railroad cut south of the water-works at Miamisburg, and along the beds of many streams, where the stone has no commercial value. In fact, limestone, sandstone, clay, and shale always occur in layers of different degrees of thickness.

Wherever fragments of limestone occur in smaller masses, these have been broken off from the much more extensive layers, of which originally they formed a part, either by the violence of some spring or summer freshet or by the wedging action of freezing water, where it has penetrated into some crevice of the rock, in winter. Massive rocks may be split by the growth of entering roots of trees. Even alternations of heat and cold may play a part, causing the exposed surfaces of rocks to expand or contract more than the less accessible inner parts. In fact, many agencies tend to reduce rocks to fragments, but these fragments at first are irregular in form and angular in outline.

All fragments remain angular until rounded by the action of running water. The farther rock fragments are traced down stream, from their parent layers or ledges, the more rounded they become. The original angular corners evidently have been ground off. The sand carried along by the stream is the chief grinding material. It is not pushed against the rock by the running water as firmly as sandpaper in the hand might be forced against a piece of wood, but the final results may be the same. The angular corners of the rock fragments gradually are rounded off. Every little freshet disturbs the position of the fragments enough to cause them to present other angles to the action of the sand. Sooner or later the more or less rounded forms which we expect among the pebbles of gravel are produced. That such a haphazard method of rounding should result in spherical forms is scarcely to be expected, and spherical forms are very rare. However, pebbles with all of their angles more or less rounded off are very common, and rounded pebbles, no matter where found, always are evidence of the former presence of running water.

The rolling action of pebbles along the bed of a stream, during high water, often may be heard by putting the ears below water level. The noise is evidence of the violence of the impact of the pebbles against each other. The quickness with which bricks along the seashore are reduced to rounded form is evidence of the effectiveness of a rolling motion in producing rounded forms. Along the Ohio river, entire barges of coal frequently are wrecked and sink to the bottom. In dry summer months, parts of the river bottom sometimes are so widely exposed that the farmers for miles around camp for days on the dry parts of the river bed and collect, from among the sands and gravel, the rounded pebbles of coal, often almost spherical in shape. Many a pile of rounded pebbles of coal may be noticed by the observant eye in the coal buckets of the natives during the early winter months, as evidence of their thrift.



Gravel pit on the hillsides northeast of the Ohmer Park area, showing the arrangements of the sands and gravels in layers. The inclined layers were produced by waters flowing toward the east (left), the successive layers representing successively later deposits of a violently flowing glacial stream.

13. The Arrangement of Gravel and Sand in Alternating Layers

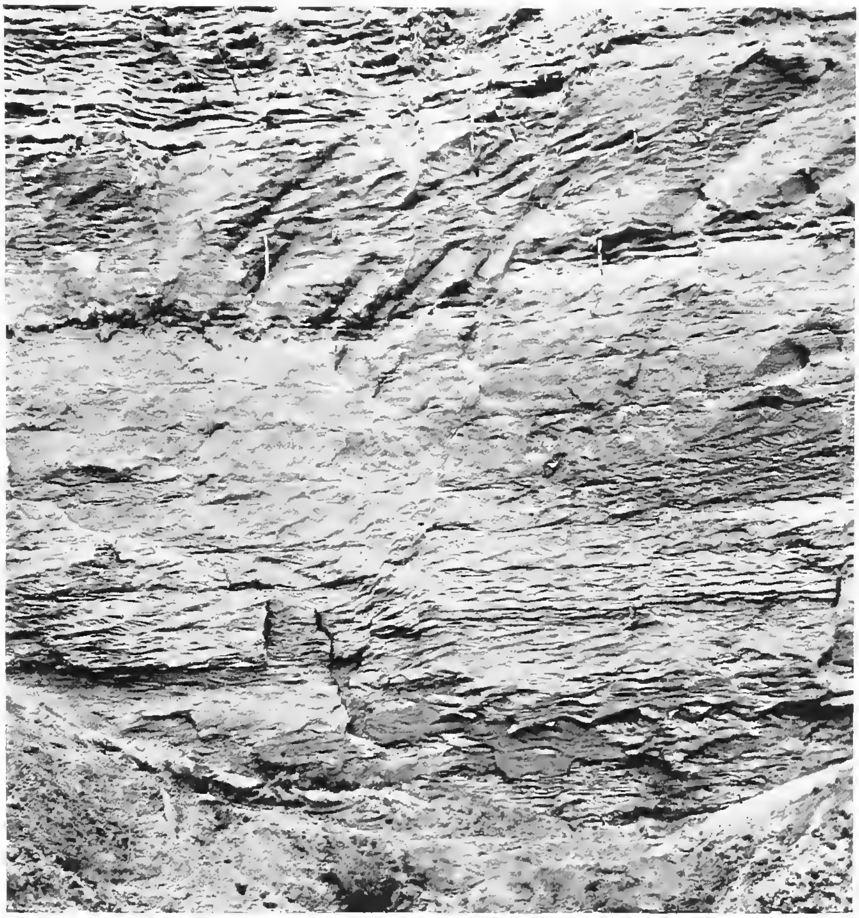
The sorting of pebbles of various sizes into layers is accomplished in nature only by the action of moving water. Any slight increase in the rate of flow of a stream causes the current to roll along fragments of slightly larger size, in addition to the smaller pebbles already set in motion. Any slight diminution in the rate of flow allows a large part of the heavier pebbles to remain, while many of the lighter pebbles continue their journey. The stationary heavier pebbles may be buried by the lighter pebbles which are continuing their travels from farther up stream. Later, the finer gravel may be covered by the lighter sands, which continue to move as long as the river is not stagnant.

Then a sudden rise of the stream may roll enough pebbles over the sand to serve as a cover before much of the sand can be removed by the rising waters, and thus the circle of deposition may be repeated over and over again,—coarser pebbles, finer pebbles, sand, finer pebbles, coarser pebbles, finer pebbles, sand,—resulting in the distribution of these materials in more or less horizontal alternating layers.

This arrangement of gravel and sand into more or less horizontal layers, differing in the coarseness of the material involved, is one of the most constant features of deposits made under the influence of running waters. It may be recognized even in deposits of the finest sand. It gives rise to the thin layers often noticed in sandstones. Occasionally these sandstones are stained beautifully with brownish and reddish tints by the presence of iron compounds. The church at the corner of Forest and Grand avenues is an excellent example of the use of such sandstones for building purposes. Also in limestones, the presence of thin layers often may be noticed, especially where their existence has been made more evident by the processes of weathering. In proof of the deposition of sand beds by running water, occasionally even the finest ripple marks are retained. Formerly an excellent example of these ripple marks was exposed in the sand beds beneath the till deposit immediately north of the railroad at the eastern extension of Irving avenue, southeast of the St. Mary's institute, in the woods long known as the "Brothers' Woods."

14. Gravel Ridges Formed Under the Influence of Running Water

We are familiar with the presence of sand and gravel in the beds of creeks and rivers. We notice their arrangement in layers, along the banks of streams, where the latter have been undermined more or less by some change in the course of the channel. When these layers of sand and gravel occur only a moderate distance above the present course of the streams, it



Ripple marks in the sand beds occurring beneath the till in the "Brothers' Woods" southeast of the St. Mary's Institute, showing the deposition of these sands in currents of water. Photographed in 1895.

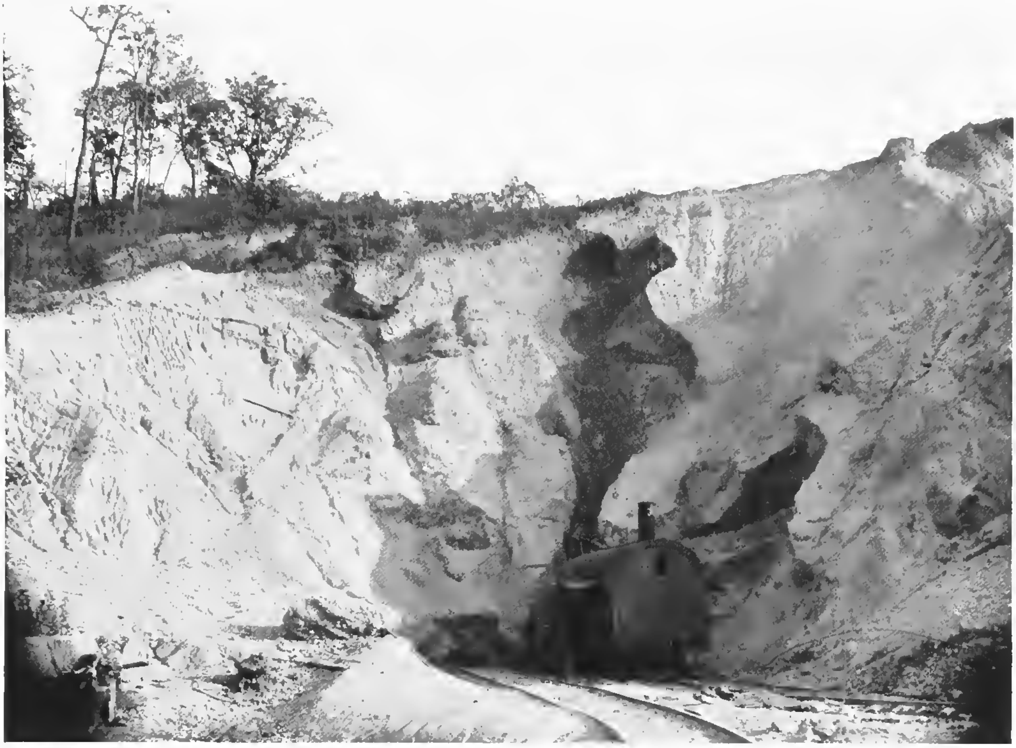
requires no great effort of the imagination to realize that their existence here indicates the former presence of running water at a higher level. Either the streams formerly were larger and filled up a larger part of the valley, or the present channel has been cut down to a lower level. However, when the layers of sand and gravel occur at the tops of high hills, the former existence of running streams at these high altitudes seems preposterous, at least at first sight, and the presence of sands and gravels at these higher levels requires more detailed explanation.

The long narrow gravel ridges south of Dayton, between Carrmonte and Delco Dell, rise far above the valley bottoms. At many points the crests of these ridges rise 80 to 100 feet above the immediately adjacent lowlands, valley bottoms, or hollows. Estimating the eastern margin of the Miami valley bottoms, between the foot of the bluffs at the Calvary cemetery and the Moraine farm at 780 feet above sea level, many of the ridges in the Calvary cemetery attain a height of 140 feet above this level. The highest point of the ridge occupied by the Calvary monument rises fully 160 feet above this level. The Pike ridge, west of the Cincinnati pike, at the O'Neil road, rises 120 feet above the eastern margin of the flat bottom lands. This elevation is attained also by the Sunset ridge, where crossed by the Big Hill road, north of the Moraine farm. Tip Top knob, at the southern end of Old Orchard hollow, equals the elevation of the highest part of the Calvary ridge, namely 160 feet above the eastern margin of the Miami valley bottom lands. The highest part of the Delco Dell ridges rises 140 feet above these bottoms. Similar high points occur along the ridges in the Hills and Dales area.

When it is realized that the tops of these gravel ridges reach elevations of 160 feet above even the most elevated part of the flat bottom lands of the adjacent part of the Miami valley, and that they rise more than 220 feet above the waters in the present channel of the river, the difficulty of accounting for the presence of these gravel ridges by the action of running water is fully appreciated. We are familiar with the lowering or cutting action of water. We know that water has produced the valleys which intersect the hills. However, we are not accustomed to think of water as building gravel ridges up to heights far above the level of the valleys. Such an idea is too suggestive of water running up hill, and appears unreasonable. Nevertheless, all the evidence is in favor of the production of the long gravel ridges, south of Dayton, by means of running water. This evidence is revealed in the numerous gravel pits and road cuts exposing the structure of the interior of the ridges.

15. Gravel Pits and Road Cuts Exposing the Structure of the Interior of the Gravel Ridges

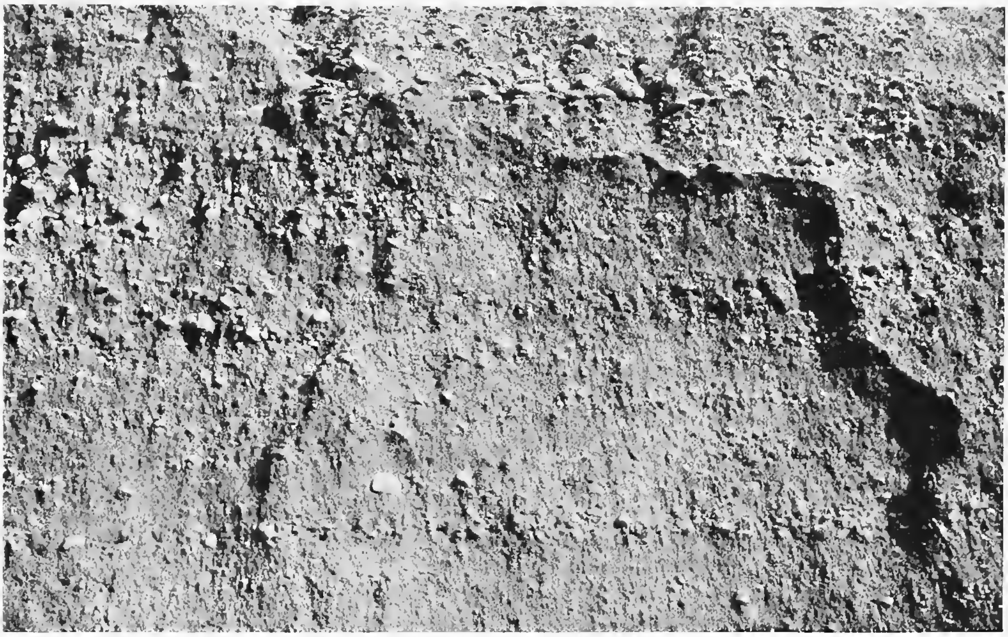
A magnificent exposure of the structure of the interior of one of the gravel ridges is presented by the gravel pit immediately north of the Cal-



Gravel pit of the Dayton Washed Sand and Gravel Company, west of the northern end of the Chapel ridge, at the edge of the Bluffs north of the Calvary cemetery.

vary cemetery grounds, where the Washed Gravel and Sand Company is cutting away the northern end of the ridge immediately west of the Calvary ridge. Here the gravel pit has a vertical face of 145 feet. Coarser gravels occur near the top. Finer sands are more abundant near the bottom. The arrangement of the gravel and sand in numerous horizontal layers is clearly in evidence. Layers of coarser gravels alternate with finer gravels, and both are interbedded at various levels with sand. The structure unquestionably is that produced by running water.

How running water could exist at these high levels and build up thick deposits of gravel and sand, apparently without the assistance of lateral confining walls, is another question, which will be taken up later. For the present, it is sufficient to emphasize the fact that the stratification of the sand and gravel, forming these ridges, into interbedded layers of different



Nearer view of gravel pit at northern end of Chapel ridge, in Calvary cemetery, showing arrangement of pebbles in layers. See page 43.

degrees of coarseness, is evidence that these gravel ridges were formed under the influence of running water.

Another excellent exposure of the structure of the interior of the gravel ridges is presented by the gravel pit at the northern end of the Chapel ridge, southeast of the chapel in the Calvary cemetery. Here the gravel pit exposes a vertical face 30 feet in height. The coarsest pebbles again occur within 15 feet from the top of the ridge, but coarse and fine gravels are interbedded in more or less horizontal layers, and evidently were deposited under the influence of running water.

At the western end of Mayo avenue, the cut through the Chapel ridge is only 12 feet deep, but is sufficient to indicate that the coarser pebbles occur near the top of the ridge.

The arrangement of the gravels in alternating layers of coarser and finer material is well shown also by the Pike ridge, at the O'Neil road cut, west of the Cincinnati pike. Here the vertical face of the cut is fully 50 feet in height, counting from the lowest part of the cut, but the basal part of the cut is covered more or less by loose gravel, brought down by slumping.

Southwest of the sub-power station on the Ohio Electric line, south of the O'Neil road, the large gravel pit exposes a vertical face 80 feet high, and southeastward, on the eastern side of the Cincinnati pike, there is a gravel pit at least 50 feet deep. Still farther southeast, at the northern end of Sunset ridge, on the Governor Cox estate, another gravel pit has a vertical face of 60 feet, and at the southern end of the Sunset ridge, on the Moraine farm, north of the Stroop road, there is still another gravel pit, with a vertical face of 65 feet.

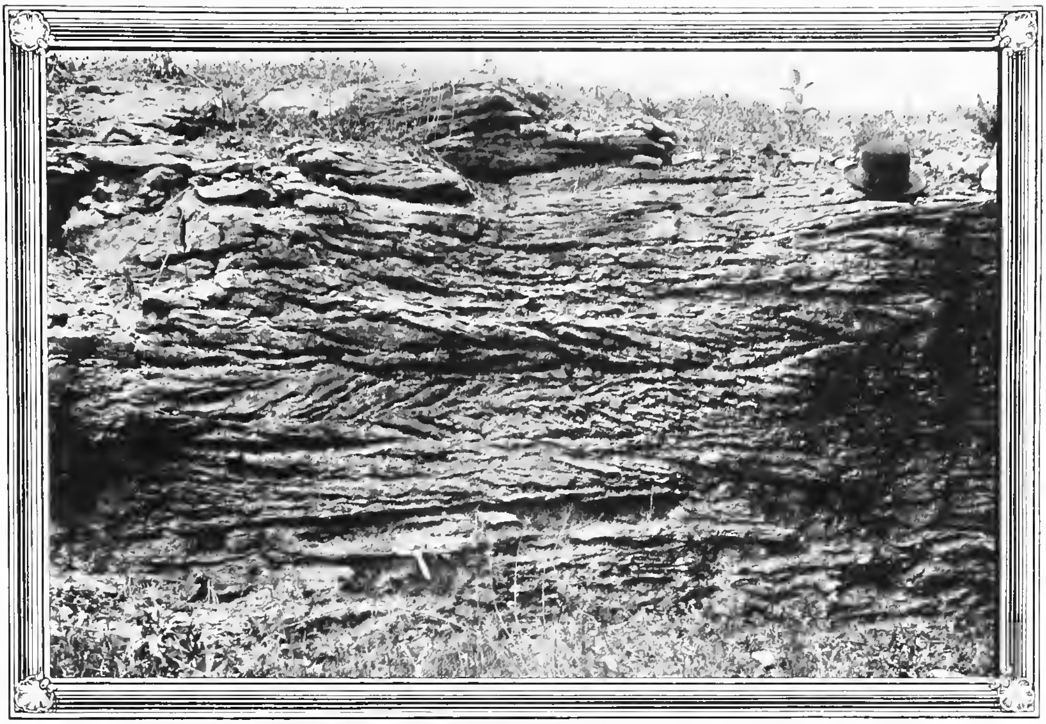
Surely these exposures are sufficient to reveal the general character and arrangement of the materials forming the gravel ridges. Since all of them agree in showing the deposition of the sand and gravel in layers, under the influence of running water, the evidence of the origin of these high gravel ridges, south of Dayton, as stream deposits, may be regarded as conclusive.

16. Gravel Ridges Deposited by Irregular and Often Turbulent Currents

The most obvious fact about the layers of pebbles and sand in the gravel ridges is their irregularity. Usually these layers are not strictly horizontal for any great distance. If any layer be traced along the face of a cut transverse to a ridge, it often will be seen to rise or fall, sometimes abutting against other layers consisting of a different degree of coarseness. Thus, the edge of a coarse gravel layer may abut against a more or less inclined layer of sand, or a layer of sand may wedge out suddenly between two layers of gravel. Frequently it is evident that one of the layers of sand and gravel formerly had a greater lateral extent, but that some change in the direction of the current caused a part of the previously deposited layers to be cut away locally, thus altering the shape of the base of the channel over which the stream flowed. Then the process of filling up the channel was begun again. Similar features are shown also in those gravel pits which expose the structure parallel to the length of the ridge.

It is evident that the base of the channels of the streams which formerly deposited these sands and gravels must have risen and fallen in a somewhat similar manner and with about the same degree of irregularity as the present crests along parts of the ridges. Such abrupt, irregular changes in the deposition of sand and gravel suggest corresponding irregular changes in the force and direction of the currents then existing, so that the conclusion can not be avoided that the gravel ridges south of Dayton were deposited by currents which often were very irregular and sometimes were very turbulent.

The coarseness of some of the gravel layers, especially in the upper 25 feet of the ridges, indicates that the currents sometimes were very swift. Pebbles 6 to 8 inches in length are abundant. Pebbles a foot long are not rare, and boulders 15, 18, and even 24 inches in length are present, but are not abundant. However, most of the material forming the gravel ridges is much finer, and implies a less rapid flow of water. By far the greater part of the material consists of coarse sand and of the smaller pebbles, usually not exceeding 3 inches in diameter. The larger pebbles may be very numerous in some of the upper layers, but they form only a comparatively small part of the total mass of the ridges. They suggest rapid currents near the closing stages of stream flow. However, some of the larger boulders may have been washed along only short distances by stream action. It will be shown later that the streams depositing the gravel ridges flowed along channels beneath a great thickness and large expanse of glacial ice, and some of the large boulders may have dropped from the roof of these subglacial stream channels, having been released by the melting of the ice.



Brassfield limestone in abandoned quarry east of fork of Brandt and New Carlisle pikes, six miles northeast of center of Dayton. Deposited by irregular currents.

CHAPTER IV

DIRECTION OF FLOW OF THE STREAMS PRODUCING THE GRAVEL RIDGES

17. Direction of Flow of the Streams Producing the Gravel Ridges

The direction of flow of the streams producing the gravel ridges may be determined much more readily than might be imagined by those not familiar with the method of conducting such researches. The procedure is simple.

South of Dayton, the streams producing the gravel ridges must have flowed either north or south, in the direction indicated by the ridges.

If the pebbles forming the ridges are merely fragments of rock which have become rounded since they were broken off from their original ledges, their origin might be ascertained in certain cases merely by determining from what kinds of rocks the pebbles have been formed, and where rocks of this kind still are to be found in their original form as layers or ledges. Should any of these rocks prove sufficiently peculiar to be identified readily, and should the distribution of the layers or ledges from which they could have been derived be such as to indicate only one possible direction for the source of the rock, then the problem would be solved.

By such methods it has been determined that many of the pebbles found in the gravel ridges could have come only from the north. Hence the streams transporting these pebbles also must have come from the north, and the associated pebbles, whose origin could not be determined so readily, evidently must have been conveyed by the same currents, from the same direction.

18. The Rocks of Western Ohio and the Adjacent Parts of Indiana

The method of determining the origin of the pebbles in the gravel ridges near Dayton will be understood more readily if the character and distribution of the rocks found in Ohio, Indiana, and that part of Canada which lies immediately north of these states be known. For that reason the following brief statement of the character and distribution of these rocks is added:

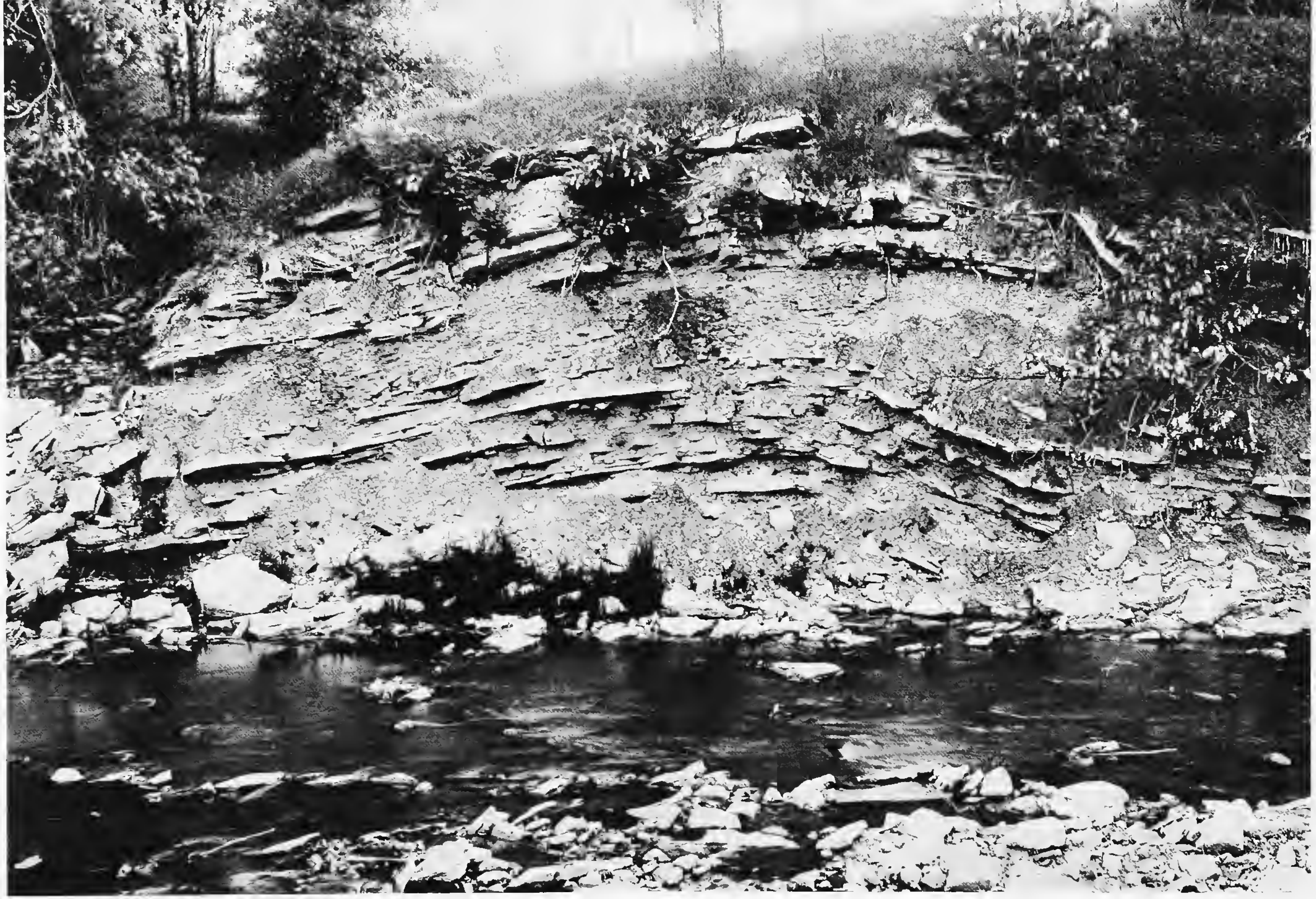
If you were to visit the gorge of the Whitewater river, at Richmond, in Indiana, you would notice a great mass of comparatively thin limestones, arranged in horizontal layers, often interbedded with more or less clay, the entire series being known among geologists as the Richmond beds. Both limestones and clays are richly fossiliferous. Many of the most interesting fossils known to geologists have been discovered in this gorge. The same strata are exposed where the Springfield traction line crosses the railroad at the northern end of Huffman hill, east of Dayton. Excellent exposures of Richmond beds, at a lower level, occur along Hole's creek, southeast of Moraine park, and, at still lower levels, in the big railroad cut along the Big Four railroad south of Miamisburg. The largest Indian mound in the United States is located on the hill summit, southeast of this railroad cut.

At the north end of the Huffman hill, east of Dayton, at a higher elevation than the exposures at Richmond, is found a massive layer of limestone, with a different texture and color, and containing a different group of fossils. This rock has been quarried for many years at Centerville, in the southern part of this county, and still is used extensively in the construction of the numerous pikes in Montgomery and neighboring counties. It formerly was well exposed in the abandoned quarry at the Soldiers' Home. For many years it was regarded as identical with the limestones known as Clinton, in New York, but at present the name Brassfield limestone is regarded as more appropriate. Its thickness varies from 18 feet near Dayton to about 30 feet northward, at Piqua. Recently the Brassfield limestone has become important economically on account of its large content of lime and its small content of magnesia. An area southeast of Tippecanoe City, near West Charleston, has been selected as the location for a large cement plant. The glacial clay deposit overlying the Brassfield limestone furnishes the necessary silica and alumina.

Overlying the Brassfield limestone is a very white and dense limestone, usually with very few fossils, formerly abundantly quarried in the vicinity of Dayton, and extensively used for window sills, porch flagging, sidewalks, and gutter stone. The courthouse, and several of the churches on Ludlow street, in Dayton, were constructed of this stone. The upper part of the quarry at Centerville furnishes an abundance of this solid white stone.

Numerous quarries formerly existed southeast of Dayton, along the Smithville road, also south of the asylum grounds, and in the vicinity of Beavertown.

The first railroad at Dayton ran from the central part of the city diagonally, southeastward, across the commons to the quarries, which at that time existed along the Smithville road, northeast of the Ohmer Park plat. Some parts of the old right-of-way of this railroad may be traced still in the woods, near the former quarries, and only a few years ago the old railway embankment could be followed from these woods for more than half a mile northwestward, toward Dayton. Under the name of Dayton limestone this rock was transported to distant localities, and was at one time extensively used in the construction of buildings, the white color of the Dayton stone producing a pleasing contrast with the red color of the brick. The Dayton limestone is overlaid by a series of limestones and clayey shales called the Osgood bed, after a locality in Indiana.



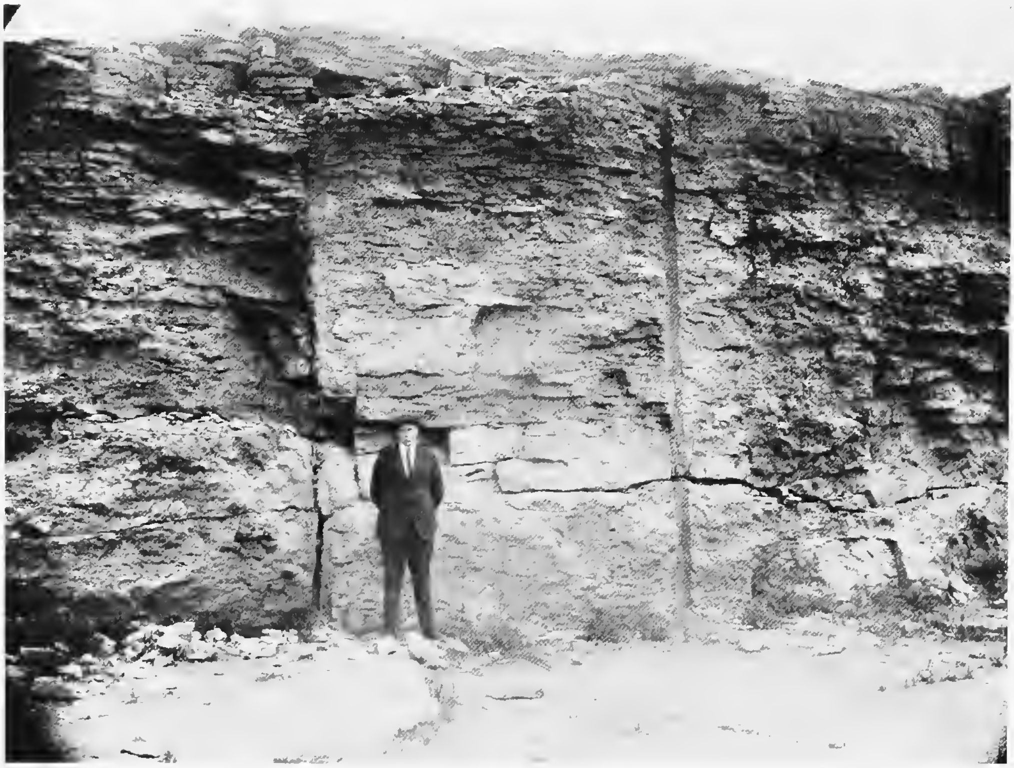
LOWER part of the Liberty division of the Richmond formation as exposed on Hole's creek south of the Bellbrook road, about three and a half miles southeast of Alexandersville. The Hebertella insculpta horizon occurs at the base of these exposures. See figure 11 on the plates of fossils, page 208, and the various vertical sections across the pre-glacial valley of the Miami river. This is a good locality for collecting fossils. Note the small bend in the rocks. When these bends take place on a vastly larger scale they give rise to mountains

On the way to Springfield, from the windows of the railroad train, cliffs of massive rock may be seen which belong at a higher level than the Osgood bed. The basal part of this massive rock, from 6 to 8 feet in thickness, is rather porous and is valuable only for crushed rock. The immediately overlying part is much more dense; it is comparatively even bedded and is quarried for building purposes. Compared with the Dayton limestone it is softer and has a more yellowish tint. The same rock is exposed at several quarries north of the Eaton pike, between Kingsville and the Union pike, about 3 miles west of Dayton. Here its thickness is 8 feet. The building rock contains an abundance of a peculiar large shell called *Pentamerus oblongus*, and is known as the Springfield limestone. The Springfield limestone contains too large a content of silica and alumina to burn into a valuable lime.

The upper part of the rock at the Springfield quarries consists of a much more massive limestone, not at all suitable for a building stone, but very useful for quicklime. In the vicinity of Cedarville, this is the only stone exposed in the quarries and hence it is called the Cedarville stone. Numerous lime kilns have been constructed where this stone is exposed. The Shoup lime kiln, 6 miles north of Dayton, on the Troy pike, east of the Miami river, still is in operation. Lime kilns formerly existed also west of Dayton, at the localities north of the Eaton pike, already mentioned. In Canada, rock corresponding to the Cedarville limestone is known as the Guelph. The Cedarville limestone is one of the three most valuable limestones utilized in Ohio for the manufacture of lime. It is an almost pure carbonate of lime and magnesia, with very little silica or alumina.

At the southern point of Put-in-Bay island there is exposed a considerable thickness of limestone, some of which is very thin bedded or laminated. This is a part of the Monroe limestone which underlies a greater part of the state of Ohio than any other large division of rock excepting the coal measures of the eastern part of the state. This limestone extends southward as far as Wapakoneta, St. Paris, Urbana, London, Washington Courthouse, and Vanceburg on the Ohio river.

In the large quarries visible from the railroad train just before enter-

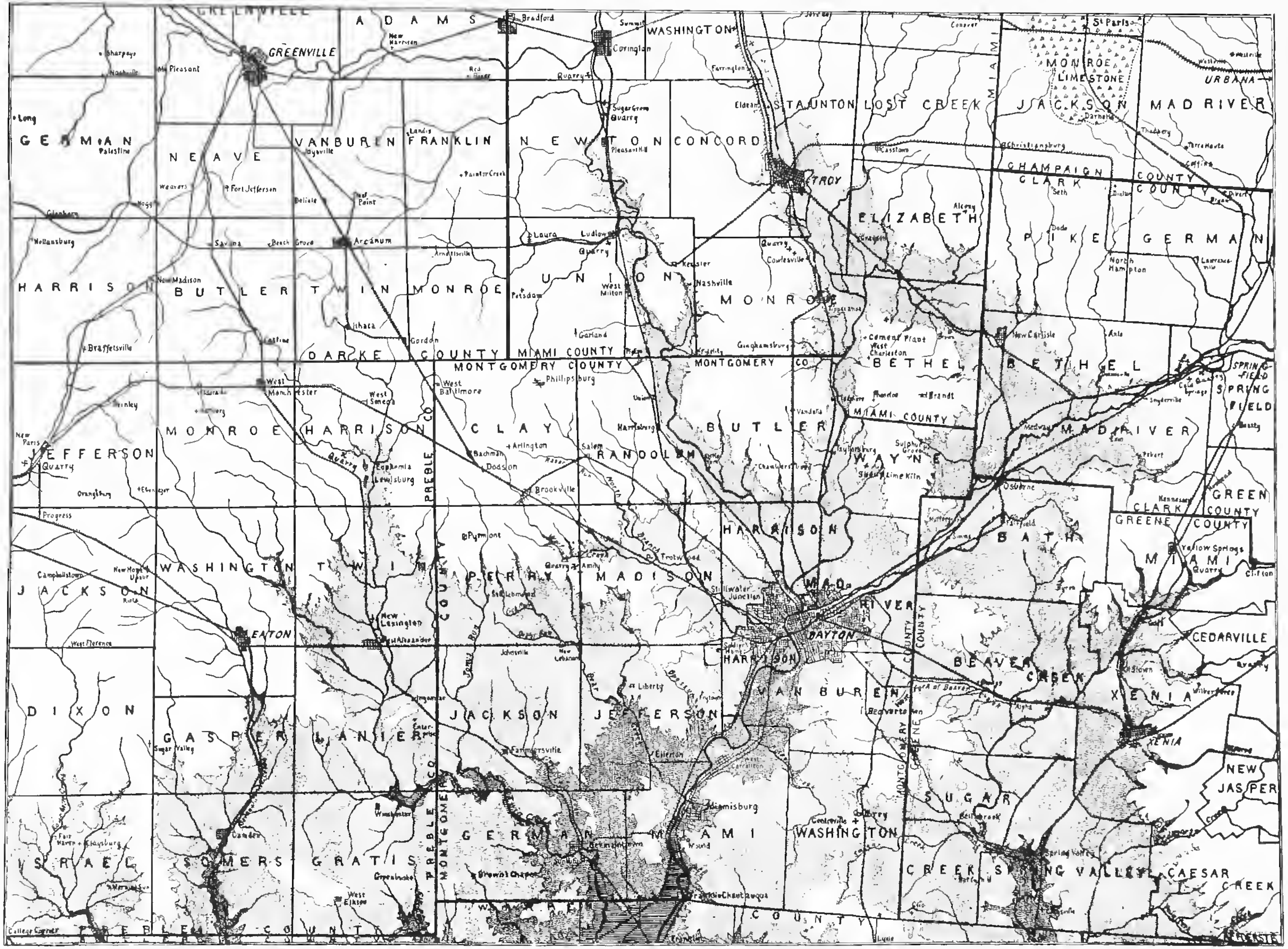


Lower part of the Cedarville limestone at the Shoup Lime Company quarry, on the old Troy pike, seven miles north of the center of Dayton. The top of the Springfield limestone forms the floor of the quarry.

ing Columbus, the Columbus or Onondaga limestone is exposed. Certain layers of this limestone contain numerous fish teeth and other fish remains. This limestone extends northward to Kelley's island, east of Put-in-Bay, and exposures are found also in Michigan and southern Ontario.

Above the Columbus limestone occurs a clayey limestone, more or less interbedded with shaly clay layers, often containing numerous shells and other remains of former marine life, readily weathering out of the clay. This limestone is exposed in various parts of Michigan and in that part of Ontario which lies between the southern end of Lake Huron and Lake Erie. It extends also southward through central Ohio to Delaware and Columbus. It is known as the Delaware limestone.

Proceeding southward from Dayton, along the valley of the Miami river, the series of thin limestones and clays, known as the Richmond group



Geological map of Montgomery and adjacent counties. The white part is underlaid by strata ranging from the Cedarville down to the Brassfield limestone. The light shaded part is underlaid by the upper half of the Richmond group of rocks, including the Elkhorn, Whitewater and Liberty. The darkly dotted part is underlaid by the lower half of the Richmond group, including the Waynesville and Arnheim. The darkly lined part, south of Miamisburg, is underlaid by the top of the Maysville group of rocks.

of rocks, continues to be exposed as far south as Miamisburg. From the vicinity of Franklin to beyond Hamilton, a lower series of thin limestones and clays, known as the Maysville group, from a locality in Kentucky, is exposed. At a still lower level, from below Hamilton to near low water in the Ohio river at Cincinnati, a third series of limestones and shales, known as the Eden group, from Eden Park, in Cincinnati, is present.

If now the names of the various limestones here mentioned be arranged in a vertical column, the name of the rock belonging lowest in the series being placed at the bottom, and the names of the overlying rocks being placed successively nearer the top, the following list would result:

Delaware limestone
Columbus limestone
Monroe limestone
Cedarville limestone
Springfield limestone
Osgood limestone and clay shale
Dayton limestone
Brassfield limestone
Richmond group of limestone and clay
Maysville group of limestone and clay
Eden group of limestone and clay.

In this form the list might be called a list of the rocks of western Ohio, eastern Indiana, southern Michigan, and southern Ontario. It is not a complete list, nor is it such a list as would be published by geologists. While most of these names apply only to minor divisions of rocks, the so-called groups include series of strata whose total thickness is vastly greater. Nevertheless, this list will serve to designate some of the rocks of interest in determining the origin of the pebbles in the gravel ridges, south of Dayton.

19. Differences Between Rocks Belonging to Different Groups or Subdivisions

On becoming sufficiently familiar with the different limestones named in the preceding list, it will be noticed that all differ more or less in their density, porosity, and hardness, and in the coarseness of their grain. Some of the limestones are well bedded, or separate readily into horizontal layers from a few inches to a foot or more in thickness. In other rocks the bedding is very irregular, or the rock may not separate readily into layers. In the latter case the rock may be called massive. In some rocks, even the individual layers are seen to be made up of many very thin sheets, which, however, do not separate readily from one another, but remain firmly attached so as to form a single, solid layer, several inches thick. Different limestones differ more or less in color. They differ often considerably in chemical composition, and although this difference may not be recognized readily by the average observer, the limekiln operator soon learns that there are differences. Some rocks are more suitable for lime than others. Some produce quick setting limes, others produce limes that set more slowly. There are differences even in the layers of the same quarry.

20. *Different Fossils Found in Different Groups of Rocks*

There are differences also in the fossils found in different layers of rock. Each of the limestones here listed is characterized by a different group of fossils.

It is taken for granted that the reader knows that fossils are merely the remains of former living animals, consisting usually of the hard parts, such as shells and bones, which have resisted decay. The term fossil may be used also to indicate impression of these hard parts and is liable to be used for almost any evidence of the former presence of life if sufficiently distinct to suggest the nature of the animal.

As a rule, it does not require a profound knowledge of fossils to be able to recognize the differences in the fossils found in different layers. The average student of geology at college does not spend 50 hours in the study of fossils, and the knowledge acquired in this short time can scarcely be called profound. Usually only a slight acquaintance with fossils is necessary to determine to what subdivision any exposure of rocks belongs, provided that the fossils occur in the rock in sufficient abundance. But it might require more expert knowledge to identify any rock with confidence if the enclosed fossils are both rare and poorly preserved. However, it would astonish most persons not familiar with such studies to observe with what speed and confidence an expert geologist, already familiar with the characteristic fossils of the different limestones can identify the latter provided that the rock be supplied fairly well with fossil remains.

21. How to Determine From What Subdivisions of Rocks Certain Pebbles Were Derived

It is quite evident that frequently it must be quite easy to determine the subdivision of limestone from which a certain pebble was derived.

For instance, pebbles derived originally from the breaking up and rounding of fragments of Clinton limestone are likely to break rather readily under the blows of a hammer. The grain is coarse and crystalline. The rock usually does not show distinct bedding. The color is salmon brown, pinkish, or gray.

Pebbles derived from Dayton limestone are likely to be hard, very fine grained, and remarkably white.

Some of the pebbles derived from the Monroe limestone are fine grained, very hard, and show that the rock is made up of numerous very thin layers, which, however, do not separate from one another readily. The color may be light blue or dove colored.

The sources of some of the pebbles may be recognized by means of the fossils which they contain. Frequently when pebbles are broken up, they are found to contain fossils which can be identified readily, and if these fossils are confined to only one or two of the various subdivisions of rocks, the source of the rock forming the pebble usually may be determined readily, the character of the rock making up the pebble assisting greatly in this identification.

For instance, the presence of the large shell, *Pentamerus oblongus* (Figure 15, on page 208), previously named, if occurring in a fairly dense, fine grained limestone of a yellowish tint suggests the Springfield limestone as the source of the pebble.

Occasionally fossils may be found entirely free of the surrounding rock. For instance, *Spirifer pennatus* repeatedly has been found in the vicinity of Dayton, in gravels and other loose deposits. It is a characteristic fossil of the Hamilton formation, the approximate equivalent of the Delaware limestone, and its source may be determined as having been that of some Hamilton rock, even if no part of the rock formerly surrounding the fossil remains attached to the latter.

22. The Source of the Limestone Pebbles Found in the Gravel Ridges South of Dayton

On investigating the pebbles found in the gravel ridges south of Dayton, no specimens which could have been derived from the Eden or Maysville limestones, in the southwestern part of Ohio, south of Miamisburg and Franklin, were noticed. This suggests that the currents of water producing these ridges did not flow from south to north.

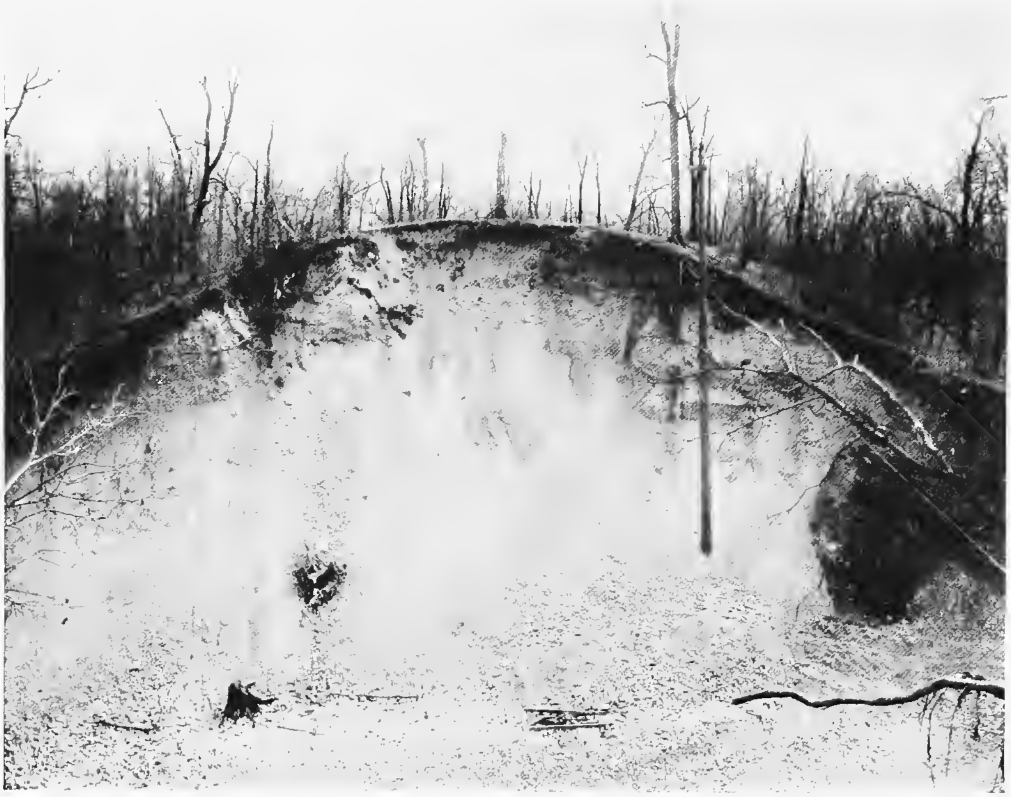
On the contrary, pebbles of each kind of rock found north of Dayton, from the Richmond limestone to the Delaware marly limestone, were found. Evidently the currents flowed from north to south.

Certain among these limestones are much more frequently represented among these pebbles than others.

Pebbles of Richmond limestone are abundantly represented and are easily recognized, usually being very fossiliferous. They form fully 14 per cent of the total number of the larger sized pebbles, 4 inches or more in diameter. The great quantity of pebbles from the Richmond limestone is explained by the fact that the rock occurs in thin layers, readily broken off; it is abundantly represented immediately north of Dayton, and the rock fragments were transported such short distances that they were not much ground up during transportation.

Fragments of Brassfield or so-called Clinton limestone are not common, but form only a small percentage of the total number of pebbles in the gravel ridges. North of Dayton this limestone forms massive cliffs not readily broken up, and the area within which this rock reaches the surface is comparatively small. Hence the probability of discovering pebbles from this source is small.

Similar statements might be made regarding the Dayton limestone.



The cut across the Pike ridge at the O'Neil road, looking southward. Notice the narrowness of the ridge along the top and the steepness of slope of the sides. The photograph was taken from too great a distance to show the horizontal bedding of the gravel and sand layers. Some of the pebbles found at this locality contained fossils known to occur only in Columbus limestone. This limestone crops out also in Ontario, on the eastern side of Lake Huron, and this probably was the origin of the pebbles.

The rock is hard and the area of exposure is comparatively small. Only an insignificant part of the pebbles in the gravel ridges consists of this rock.

By far the largest proportion of the limestone pebbles occurring in the gravel ridges consist of Springfield, Cedarville, and Monroe rock, with the Cedarville apparently largely predominating. These three limestones furnish about 70 per cent of the total number of pebbles 4 inches or more in diameter. Of course, these rocks are present in the form of continuous layers or ledges over wide areas north of Dayton.

Several pebbles of Columbus limestone, containing excellent fossils, easily recognized, were obtained along different parts of the gravel ridges between the Calvary cemetery and Deleo Dell. The original ledges from which these Columbus limestone pebbles were obtained occurred either in the extreme northern part of the state or farther north, in Michigan and Ontario. The rock is rather soft and easily broken up. The area of exposure northward is not very great and the distance over which transportation took place was considerable. Hence not many pebbles of this rock are to be expected. Although the Columbus limestone is abundantly exposed near Columbus, Ohio, it is known that the direction of transportation of the rock toward Dayton was from the north, not from the east.

Evidently the very soft marly Delaware limestone was not well adapted for distant transportation, and only occasional pebbles of rock or free fossils from this source are found.

This leaves 16 per cent of the total number of larger sized pebbles in the gravel ridges south of Dayton not accounted for. This 16 per cent of the total number of pebbles does not consist of any of the limestones listed above, but is made up of the granitic and metamorphic rock materials, discussed on pages 71-74.

23. *The Sandstones and Shales of Northwestern Ohio and Adjacent States*

Western Ohio, eastern Indiana, southern Michigan, and southern Ontario are pre-eminently limestone countries. North of Dayton the various limestones are interbedded with very little clay or clay shale, and practically none of this softer clay or clay shale can be identified among the materials forming the gravel ridges south of Dayton.

In the northern part of Ohio a little sandstone is interbedded locally in the middle of the Monroe limestone, but no pebbles of this sandstone have been recognized among the pebbles at Dayton. In fact, sandstone of any sort or derivation is exceedingly rare among these pebbles. Occasionally, a fragment of sandstone occurs which appears to have been derived from some northern equivalent of the Waverly sandstone, as exposed in various parts of the southern peninsula of Michigan.

Considerable Ohio black shale underlies various parts of northwestern

Ohio and adjacent Michigan, but none of this black shale appears among the pebbles at Dayton. It is entirely too soft to bear transportation for such a long distance.

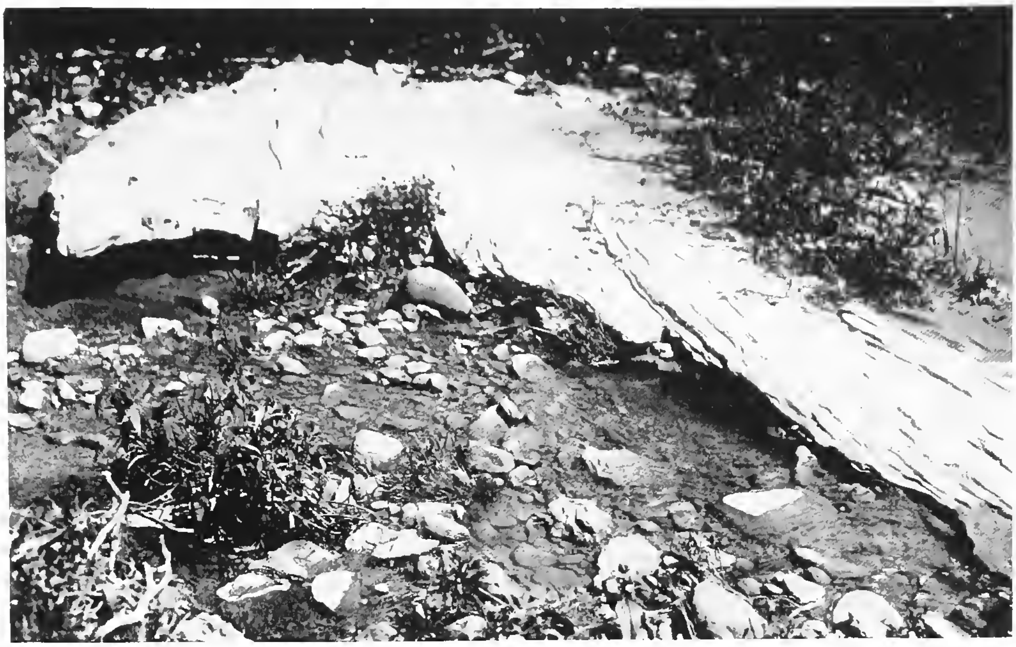
In order of succession, the Ohio black shale belongs above the Delaware limestone and is overlaid by the Waverly sandstone.

23A. How Rocks Are Formed

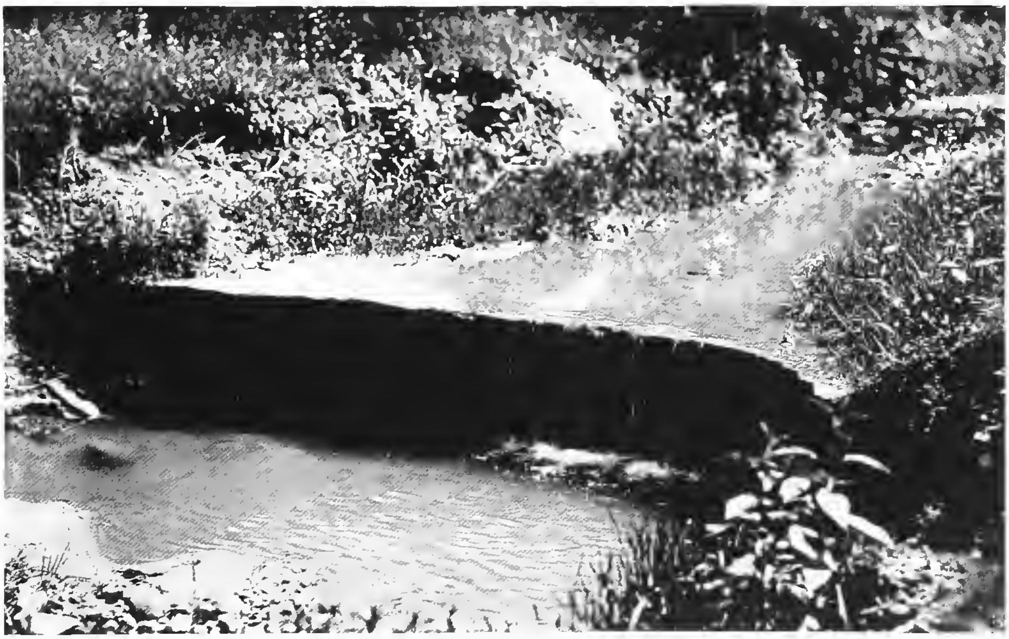
Every one is familiar with the fact that when gravel or sand are mixed with cement or lime in the presence of water, the entire mixture finally becomes hard, like rock. In fact, it *is* rock. It is just as much rock as any found in nature. It differs merely in having been formed artificially. Ordinary rock, such as sandstone and limestone, also consists of sand or fossil fragments cemented together by natural cement or lime.

In the case of sandstone, the cemented fragments consist chiefly of small particles of quartz, and the cementing material may be either lime, silica, or some iron compound. In the strongly colored red or brown sandstones, such as those used for the construction of the church at the corner of Forest and Grand avenues, in Riverdale, the cementing material consists chiefly of iron compounds. In the case of the ordinary sandstones, lime frequently is the cementing material.

The process is simple. Water percolating through decaying vegetation or animal material absorbs carbon dioxid gas, and in the presence of this gas dissolves minute quantities of the limestone through which it passes. At greater depths, where the water is under greater pressure, the amount of limestone dissolved is greater. On coming to the surface, where the carbon dioxid gas escapes, all of this limestone can not be held in solution, and part of it is deposited. At some localities it is deposited in such large quantities on old sticks and leaves which may happen to lie around at the point of exit of the seeping water that these become encrusted with lime or are entirely covered by the same. In these cases, on breaking open the lime deposit, beautiful impressions of leaves of trees often are found. Excellent examples of such leaf impressions are found by breaking up the porous, reddish brown lime incrustations at the western end of the lake in the Glen at Yellow Springs.



A thin sand layer consolidated into rock. In the bed of the brook running through the Dr. Scheibenzuber farm.



Thin layer of sand consolidated into rock and now forming the top of a little waterfall. In the bed of the brook running through the Dr. Scheibenzuber farm.

Where this lime is deposited in the crevices between sand grains, the loose sand becomes converted into sandstone. Sometimes parts of gravel beds are converted locally into solid rock. Excellent examples of this occur around Dayton. Large masses of consolidated gravel deposits formerly were seen along the bluffs, west of the Jewish cemetery, northeast of Carrmonte. Interesting examples are seen along the brook running southwest of the Dr. Scheibenzuber house toward Delco Dell. At one locality a thin sand bed has been consolidated into a hard sandstone, and along both branches of the brook this sandstone has given rise to a tiny waterfall.

Farther up stream, thicker layers of gravel have been consolidated into rock layers, the fragments of which have fallen down the hillside, toward the brook. In these consolidated fragments the original pebbles of the gravel may be recognized readily. Sometimes the consolidation of the gravel is not uniform and very irregular blocks result, often producing very picturesque effects.

At one locality along the western margin of the Mad River road, a little over half a mile south of the David church, the unconsolidated part of one of these cemented gravel layers has been washed away so as to leave a part of the cemented gravel layer behind in the form of a tiny rock bridge. Picture on page 149.

What causes the lime to be deposited in one layer of gravel without affecting to any great extent the layers of sand or gravel at lower or higher levels, of course, can not always be determined. Frequently the cemented layer is underlaid or overlaid by a more clayey layer through which the water does not percolate readily.

In the case of the coarser grained limestones formed at the bottom of the sea, the grains usually consist of fragments of shells or other marine organisms which have become rounded by the wash of the waves and consolidated by the infiltration, between the fragments, of mud impregnated with lime. In the course of ages this mud and lime harden into rock, binding the entire material together. In some limestones the mud element may form quite a considerable part of the consolidated rock. In other limestones even the infiltrated mud may be calcareous so that the limestone

Several gravel boulders along the northern edge of the brook running through the Dr. Scheibenzuber farm.

Gravel boulder north of the brook running through the Dr. Scheibenzuber farm. Large holes have been weathered into this boulder.

may be quite pure. The coarser the original fragments of shells and other organisms, the coarser will appear the grain of the rock. In some limestones the original deposit must have consisted almost entirely of calcareous mud since no grain can be recognized excepting under the microscope.

From the preceding notes it will become evident that sandstones and limestones are formed by the cementing together of grains of sand or particles of shells or other calcareous materials, sometimes readily distinguishable and at other times too fine to be readily recognized as made up of individual particles.

People sometimes ask: Do stones grow? A man once removed a very large Canadian boulder at considerable expense because he was afraid that if it were used as the support of part of a foundation wall it might grow and eventually split the foundation wall. Others have said that they knew of specific instances of boulders in the fields which had grown within their lifetime. Of course, in this sense rocks never grow. It is not always possible to determine how such erroneous impressions originate. Perhaps in one case the soil was washed away by rains from some boulder and allowed more of the lower part of the rock to be exposed. In another case, a foundation wall may have settled more where resting upon gravel than where supported by a large boulder, thus giving the impression that the latter had grown. It often is easier to start an erroneous impression by inaccurate observations than to correct this impression after it has become more or less general.

23B. The Crume Sand Lime Brick Company

The use of lime as a binding material in the conversion of loose sand into solid rock is illustrated by the sand lime brick industry. The process may be seen at the Crume plant, southwest of Dayton. A picturesque walk through the woods leading westward from the southern gate in the fort at the Calvary cemetery leads directly to the plant. The path diverges toward the right from the main woodland road passing southward from gate of the fort, the latter being at the edge of the woods southwest of the Calvary monument. An enormous sand pit has been opened by the company along the western edge of the bluffs. The sand is mixed with lime in definite proportions, and then the mixture is pressed by machinery into the form of bricks. The scarcely coherent bricks are then loaded on trucks and run into long iron cylinders about 6 feet in diameter. The cylinders are closed and steam is turned on. The lime is converted by the steam into slaked lime and this soon hardens, converting the comparatively loose sand into hard brick. The longer this brick is exposed to the air, the more it takes up carbon dioxid gas, gradually converting the binding material into carbonate of lime or limestone. The brick company, in producing its brick, merely does in a short time what nature accomplishes on a much larger scale, but also in a vastly longer period of time, in converting loose material into sandstone or limestone.

24. Rocks Originating Far Below the Surface of the Earth

Limestone, beds of clay, shale, and sandstone are all rocks originating at the surface of the earth, usually as water deposits, and most frequently as deposits on the bottom of the ocean.

Volcanic rocks are those which in a melted form have flowed through openings or cracks in the overlying rocks until they have reached the surface, as lava. When this lava cools within the cracks without reaching the surface of the earth, it is called a dike rock, and when it melts its way in enormous masses upward through part of the overlying rocks and cools long before reaching the surface, it may be called a deep-seated rock. Granites are deep-seated rocks, exposed at the surface of the earth only where the originally overlying rocks have been removed by millions of years of weathering. Granites most commonly are grayish and reddish in color, but some of the deep-seated rocks, such as diorites and diabases, have so many dark colored minerals, such as biotite, hornblende, and augite, that the general color of the rock is dark green or blackish.

None of these rocks—lavas, dike rocks, or granitic rocks—occur in Ohio, Indiana, or in the adjacent parts of Michigan or Ontario except as fragments brought in by some agency from ledges occurring in some more northern areas. Nevertheless, representatives of these rocks occur among the pebbles in the gravel ridges south of Dayton, forming about 10 per cent of the larger pebbles, meaning by this those pebbles which equal or exceed 4 inches in diameter. Of this 10 per cent, 6 per cent consists of reddish granite, and 4 per cent of the dark-colored diorites and diabases, indicating that very few rocks originating as lavas or dike rocks are present, since they are not sufficient in number to equal even one per cent of the total.

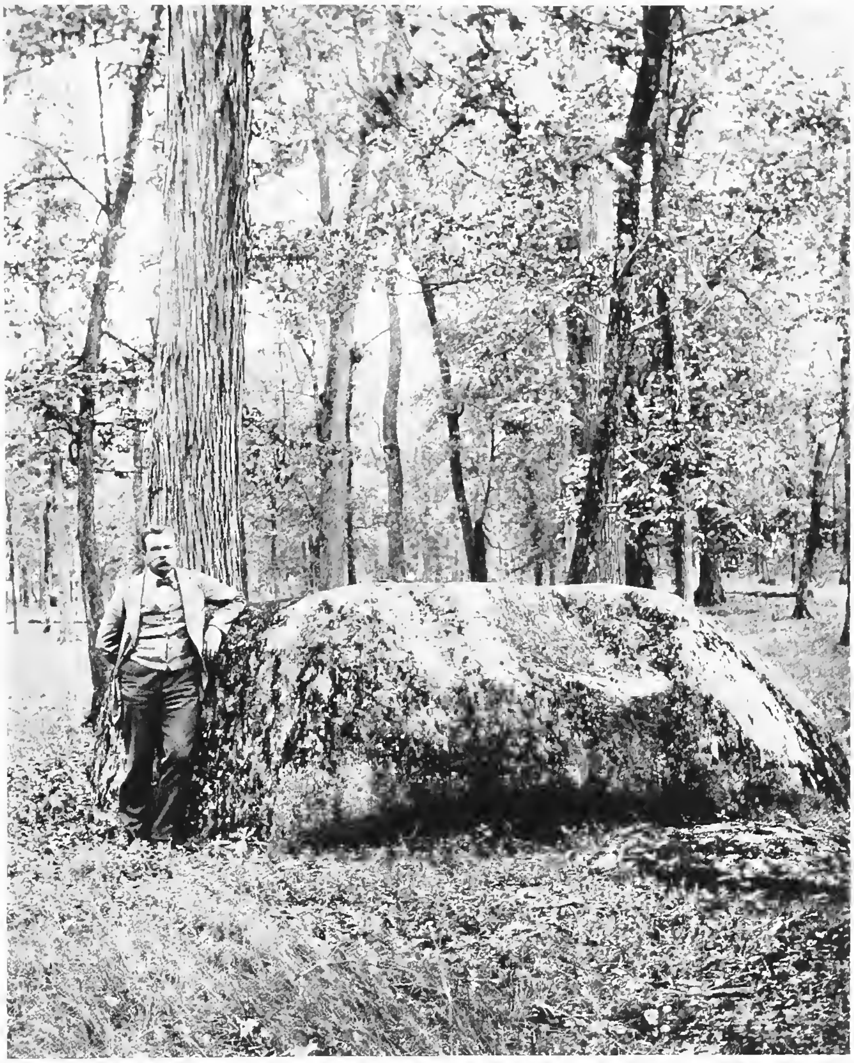
The source of the granitic rocks occurring as pebbles in the gravel ridges is in Canada. If a line be drawn from the extreme northeastern corner of Lake Ontario westward to the most eastern angle of Georgian bay, and thence along the northern shore of this bay and of the channel north of Manitoulin island westward as far as Marquette, on the southern shore of Lake Superior, then a long east and west line would be secured, south of which the prevailing rocks are limestone, with lesser amounts of sandstone and shale, while north of this line the deep-seated granitic rocks are common, forming the prevailing rock ledges over large extents of country. It is the restriction of the granitic rocks to these Canadian territories, among areas not too remote from Ohio, which gives greatest assurance to the average observer of the northern origin of the pebbles found in the gravel ridges south of Dayton.

It requires some familiarity with fossils and with the different subdivisions of the rocks in which they occur to be able to appreciate that a certain pebble indicates derivation from a northern source, and hence a southward flow of waters. However, very little information is needed to recognize certain pebbles as granite, and as different from any rock found in the form of ledges within Ohio or Indiana. Hence, the presence of granite pebbles is more commonly cited as an evidence of the northern source of the pebbles in the gravel ridges, although the fossils of some of the limestone pebbles furnish equally definite evidence.

25. *The Quartzite, Gneiss, and Other Metamorphic Rocks of Ontario*

Sandstone, under the influence of great pressure and heat, in the presence of moisture, is altered into a much harder rock called quartzite. This frequently has a whitish or reddish color, and often has a crystalline, more or less glassy appearance, owing to the enlargement of the quartz particles of the original sandstone.

Under the same influences of abnormal pressure and heat, granitic rocks have been altered to rocks in which the minerals are more or less arranged in bands or thin layers, often differing in color, and sometimes more or less contorted. These granitic rocks are then called gneisses.



The Lambert boulder, 46 feet in circumference, found in the woods twelve miles west of Dayton. One of the granitic rocks of Canadian origin.

When altered sandstones, argillaceous rocks, or granites are so abundantly supplied with mica or hornblende, arranged in approximately parallel directions, that the rock splits more or less readily parallel to these minerals, the rock is called a mica or hornblende schist.

Quartzites, gneisses, and schists are abundantly represented among the pebbles of the gravel ridges south of Dayton. They form about 6 per cent of the total number of the larger sized pebbles present.

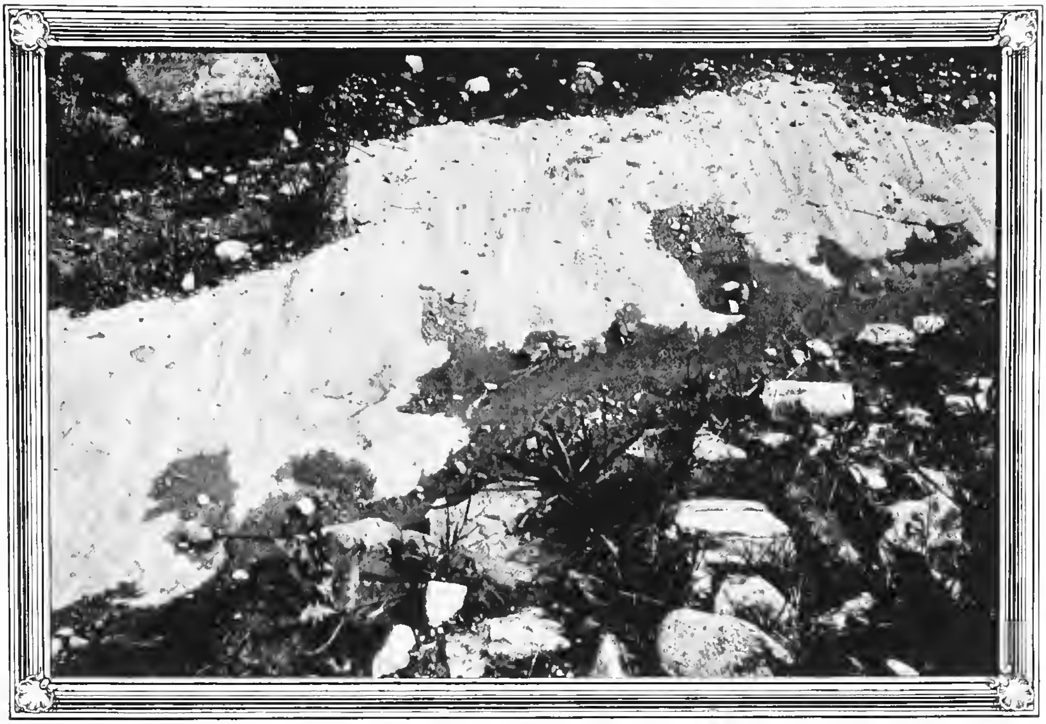
Since they occur, as solid ledges in this section of the country, only north of the boundary line separating the limestone areas from the igneous rock areas, in other words, north of Lake Ontario, Georgian bay, the north channel of Lake Huron, and Lake Superior, it is evident that the presence of quartzites, gneisses and schists among the pebbles is further evidence, if any were needed, of the northern origin of these pebbles.

26. The Streams Producing the Gravel Ridges Were of Short Length

Although the evidence is clear that the streams which deposited the gravel ridges south of Dayton obtained these materials from the north, this does not prove that these streams were of any great length. In other words, running water may have been only one of the transportation agencies bringing these rocks from their northern sources. It may have been only the last active agency, and the one which produced the least result, as far as the distance they actually moved the rocks is concerned. Previously to the action of water, some other transportation agency may have been at work.

This transportation agency was the ice, in the form of a glacier of enormous size.

We shall see later that the streams producing the gravel ridges probably were of short length, in some cases only a few miles. However, no matter how short, if their direction of flow had been northward, some of the pebbles would show evidence of southern origin, and this is not the case.



Glacial striæ running 15 degrees east of south across the upper surface of the Brassfield limestone. Photograph taken along the road crossing the hill a little over a mile west of Simms station, two and a half miles northeast of Harshmanville.

CHAPTER V

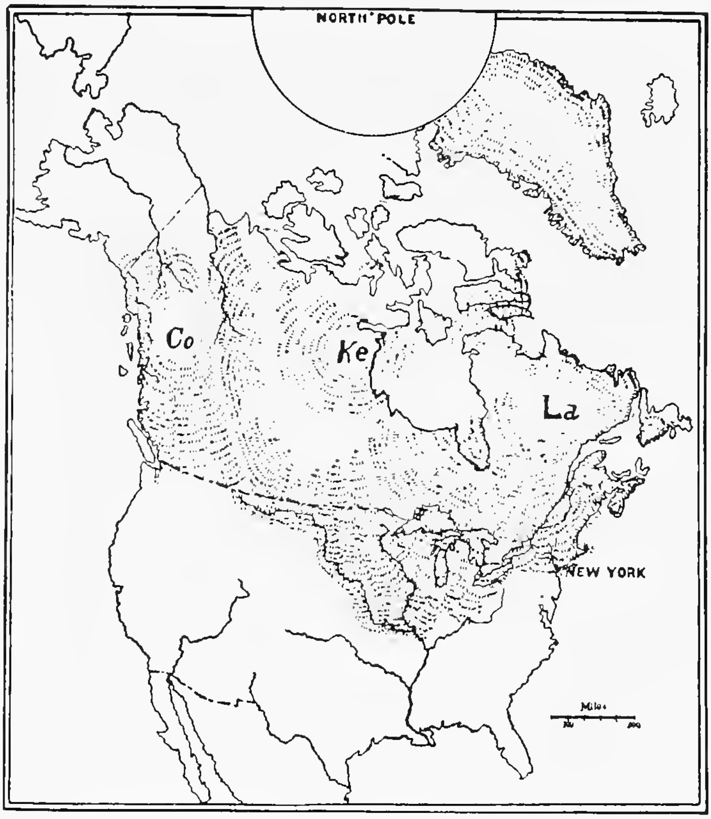
DIRECTION OF MOTION OF THE GLACIAL ICE

27. The Glacial Ice Sheet; Its Extent and Centers of Distribution

As already indicated in the preceding lines, the greatest transporting agency in moving fragments of rock from Canada, and from the nearer areas north of us, southward, toward Dayton, was the ice, in the form of a glacier of such large size that usually it is referred to as a continental glacier.

This continental glacier covered most of the northern part of the North American continent excepting certain parts of northern Alaska. It originated in various areas from which the ice spread until it formed a more or less continuous sheet.

Even after the ice sheet was continuous there were certain areas where the accumulation of ice appears to have been greatest, and which served as centers of distribution from which the ice sheet spread in a more or less radiate direction southward. The so-called Labrador center occupied the broad peninsula between Hudson bay and the coast of Labrador. From this center the ice spread southward to Long Island, New Jersey, Pennsylvania, Ohio, Indiana and Illinois, reaching the northern border of Kentucky between Cincinnati and Louisville at various localities.



Map of North America during the glacial ice age, showing the Cordilleran, Keewatin and Labradorean centers of accumulation from which the ice moved. Note that the continental ice sheet reached only the southern margin of Alaska. (After Chamberlin.)

The Keewatin center occupied the broad territory between Hudson bay and the rockies. From this center the ice spread southward to northern Missouri, eastern Kansas, Nebraska and South Dakota, and the northern parts of North Dakota and Montana. The Labrador and Keewatin ice sheets met, and at times more or less overlapped, along a line extending along the upper parts of the present Mississippi river and the axis of Lake Winnipeg.

The Cordilleran center occupied the northern Rockies and the ranges farther westward. From this center the ice sheet spread into northern Washington and Idaho, and northwestern Montana.

28. *The Glacial Ice Lobes*

From each of these centers of distribution the ice sheet spread southward, but to various distances, producing an irregular ice front. As was to be expected, the ice sheet spread farther southward along the lowlands than over the more elevated areas, forming large lobes.

Thus, during one of the later stages of the ice sheet, the Miami lobe extended down the Miami river to within a short distance of Cincinnati, occupying the territory between Xenia, in Ohio, and Connersville, in Indiana.

The Scioto lobe extended as far south as Hillsboro and Chillicothe, and spread laterally from Xenia on the west to Lancaster, Newark, and Mt. Vernon on the east. The main axis of this lobe lies along the Scioto river. In a similar manner the Maumee valley, Saginaw Bay, and Lake Michigan formed the axes of glacial lobes.

29. *Direction of Motion of Glacial Ice*

If the pebbles in the gravel ridges south of Dayton originated from localities north of Dayton, in some cases from localities even as far north as Canada, and if these pebbles were transported not only by the streams forming the gravel ridges, but also, during their earlier stages of travel, by the very slowly moving glacial ice, then not only the ridge-building streams, but also the transporting glacial ice sheet must have moved southward.

By far the largest part of the transporting was done by the moving ice sheet. The streams, at the southern margins of the ice sheet, however, probably did most of the work of rounding the rock fragments into pebbles, and certainly did all of the work of sorting the pebbles and sand into layers.

30. *The Direction of Motion of the Glacial Ice Near Dayton Indicated by Glacial Striæ*

The direction of motion of the glacial ice frequently is indicated locally also by long, straight scratches or striæ cut into the uppermost layers of the continuous sheets of rock.

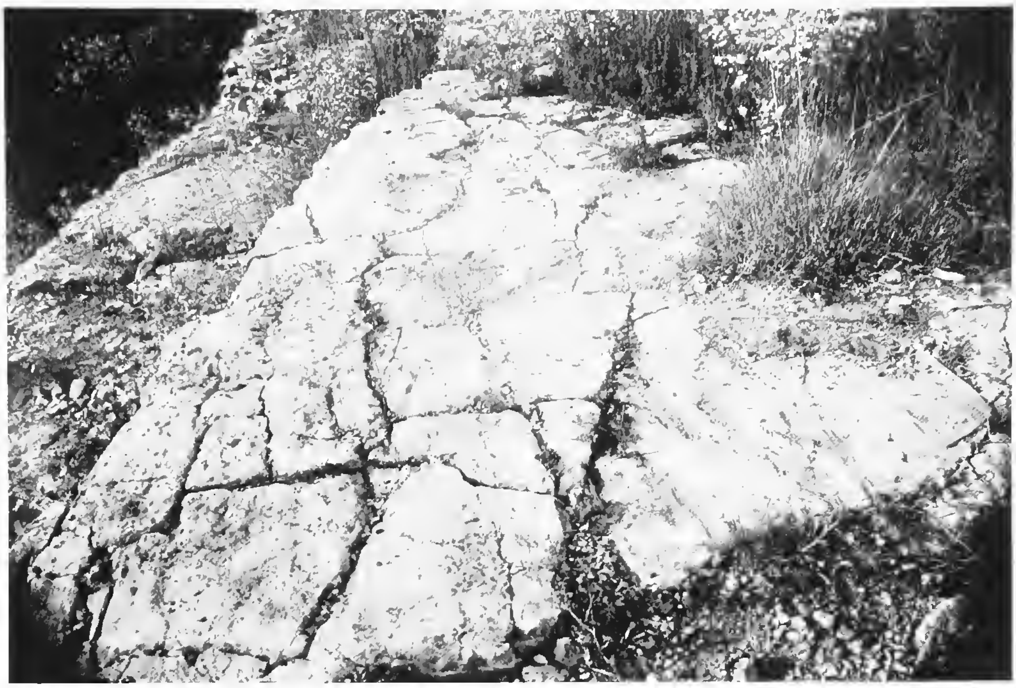
In former years, when the numerous quarries in the vicinity of Dayton were worked extensively, large surfaces of rock often were laid bare by the removal of the overlying clay, gravel, and soil, preparatory to the wedging or blasting out of the underlying rock. In these cases, the exposed surface of the topmost layer of limestone, directly beneath the clay or soil, was found smoothed as though by some enormous planing machine. Crossing the smoothed surfaces of the rock were numerous scratches or striæ. Some of these were large enough to be called grooves, but by far the larger number were quite narrow and of very slight depth. Many of these finer striæ were not likely to attract attention except when closely observed by a keen investigator.

The most striking feature about these striæ was their straightness and their comparative uniformity of direction. Not only in the same quarry, but sometimes over wide areas, the general direction of these striae was quite uniform.

From this it is evident that all of these striæ owed their existence to the same general cause. The same agency must have smoothed all of these rock surfaces.

Many of these striæ could be followed locally across the entire area of exposure, sometimes for distances of more than 100 feet. On close examination many of the striæ were seen to cross each other, but the great majority maintained about the same general trend.

In the area between Centerville, 9 miles south of Dayton, and Troy, 18 miles north of Dayton, the striæ have a southeasterly course. At the large quarry a third of a mile northwest of the railroad station east of Centerville, the direction is S 47 degrees E. See page 89. This expression means



Glacial striæ running 10 degrees east of south across the upper surface of an exposure of Springfield limestone at the eastern margin of a quarry three-quarters of a mile west of Kingsville, along a short east and west road north of the Eaton pike.

that the direction followed by the striæ deviates 47 degrees toward the east from a direct south line. At the abandoned limestone quarries along the western edge of Beavertown, or Dean postoffice, the direction is S 27 degrees E. Half a mile south of the Soldiers' Home grounds, on the eastern side of the West Carrollton pike, the direction is S 35 degrees E. At the road crossing one mile northwest of Kingsville, a mile north of the Eaton pike, the direction is S 25 degrees E. Three quarters of a mile west of Kingsville, at the quarry visible north of the Eaton pike, the direction is S 10 degrees E. This quarry, located north of a small east and west road, presents the best exposure of glacial striæ at present readily accessible in the vicinity of Dayton. At the top of a small gully in the Miller woods, west of the Union road and north of the Eaton pike, the direction is S 15 degrees E.

A mile and a quarter east of Taylorsburg, and a quarter of a mile west of Shoup's lime kiln, the direction of the striæ is S 27 degrees E. At this locality the top of the Dayton limestone formerly was well exposed in a large open quarry along the east and west road, a quarter of a mile west of the old Troy pike. The removal of very little soil would again result in a remarkably fine exhibition of striæ. At the top of the falls, in the woods half a mile southwest of Charleston, glacial striæ vary between S 20 degrees E and S 30 degrees E at different points located within a short distance of each other. Along the edge of the bluff overlooking the Miami river, two miles north of Tippecanoe city, striæ running S 28 degrees E were found, but a single layer of rock, northeast of the Crystal spring, at this locality, showed striæ running S 45 degrees E. This rock layer was 18 feet above the railroad level, and sufficiently far below the flatlands back of the bluff to show the influence of topography upon the direction of these striæ. It is quite evident that in this case the striæ run parallel to the course of the neighboring channel of the Miami river. Ordinarily, the topography does not appear to have any great influence upon the direction of these striæ.

Directly east of West Milton, seven and a half miles west of Tippecanoe city, the direction of the striæ is S 30 degrees E. Along the road across the hill, about a mile west of Simms station, the striæ run 15 degrees east of south.

31. The Spreading of the Ice Toward the Margin of the Miami Lobe

All of the localities here mentioned occur along the eastern side of the Miami lobe of the glacial ice sheet. Along this eastern side the general direction of motion of the ice evidently was about 30 degrees east of south. Nearer the middle parts of the lobe, for instance, a few miles northeast of Hamilton and northeast of Oxford, the direction of the glacial striæ was more southerly, and along the western margin of the lobe, at New Paris, in Ohio, and also north and west of Richmond, in Indiana, their course was southwest.

A study of all the striæ found within the area covered by the Miami lobe suggests that along the central axis of this lobe the general direction of flow was southward, and from this central axis the ice spread out toward the southeast and southwest, toward the lateral margins of the lobe.

Farther north, where the Miami lobe merged into the general body of the continental ice sheet, the flow of the ice appears to have been more from the northeast. Apparently that part of the ice which farther south became sufficiently separated from the ice front on the east and west to be distinguished as the Miami lobe, crossed the central part of Lake Huron, with the adjacent parts of the southern peninsula of Michigan and Ontario, and flowed in a general southwesterly direction as far as Celina, in Ohio, gradually taking a more southerly course farther southward. See diagram on page 83.

This direction of flow would bring toward Dayton the granites, gneisses, schists, and quartzites from the areas north of Lake Huron. Rocks from areas distinctly east and west of this axis of flow should be rare or absent. For instance, in the vicinity of Dayton there should be no ice transported rocks from areas east of a line connecting Xenia, Springfield, Urbana, Bellefontaine, and Kenton, and rocks from areas east of Tiffin and Sandusky probably also should be rare if not entirely absent. For similar reasons, rocks from Indiana and the western half of the southern peninsula of Michigan should be rare or absent.

32. *Glacial Striæ Produced by Rocks Pushed Along by the Ice*

The glacial striæ evidently were produced by some agency moving in a general direction from north to south. In the vicinity of Dayton, on account of its location on the eastern side of the Miami lobe, the direction of the striæ diverges toward the southeast. In other areas similar divergences toward the east or west from a southward direction are known.

The evidence of a general southward, rather than northward motion of the ice, in the vicinity of Dayton, sometimes is very interesting. Occasionally some fossil, or piece of chert or other hard substance in the rock will resist wear better than the surrounding softer limestone. In that case it may give rise to a small elevation above the general surface of the limestone, toward the south of which the rock is more or less protected from the moving glacial ice, and hence less scratched for a short distance, while toward the north the glacial scratches may be very distinct.

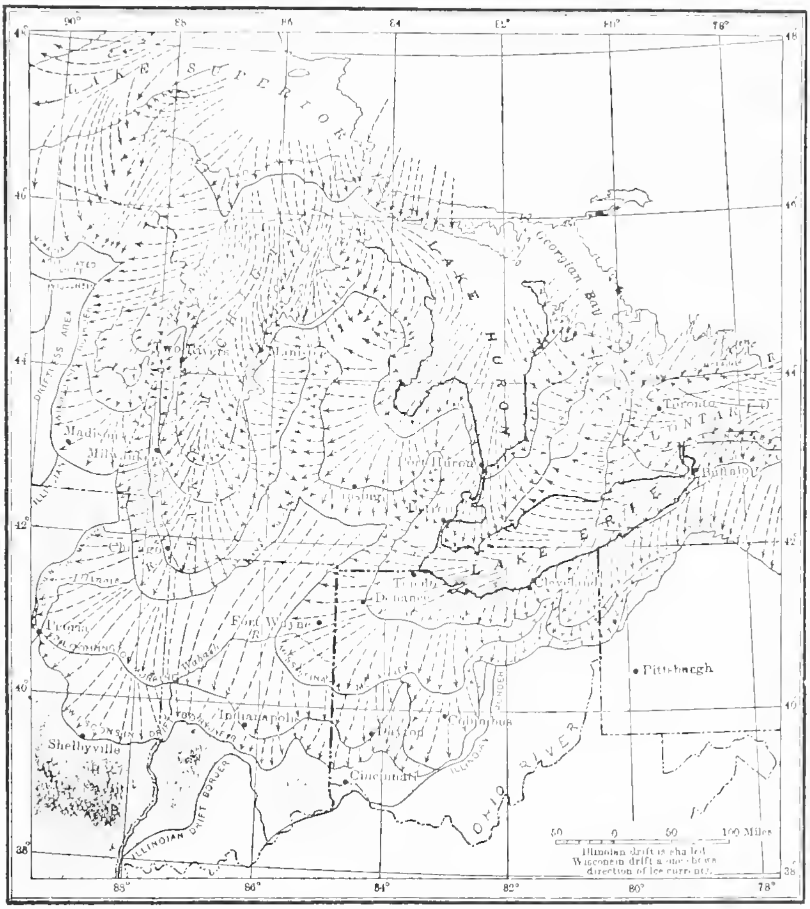
In a similar manner, but on a much larger scale, glacial scratches are likely to be less in evidence on rock slopes descending toward the south, toward some valley, than along rock slopes rising toward the south, especially if the amount of slope be considerable. Evidently the southward-facing slopes were more sheltered, while the northward facing slopes received the impact of the moving ice more directly.

Resting upon the top of the smoothed and striated rock surfaces frequently are found small rocks, or even boulders, which themselves are smoothed and striated. This early suggested that the smoothing, and striating or scratching had been done by some agency which rubbed these rock fragments or boulders against the immediately underlying surface. Of course, this must have happened before the masses of clay, sand, and gravel, which now cover most of these smoothed rock surfaces, were present.

At first this agency was supposed to consist of icebergs, which were carried by currents of water in a general southerly direction across a land surface at that time supposed to have been covered with great bodies of water, the "Great Flood." It soon was recognized, however, that such icebergs would become stranded readily on striking some shallow part of the sea bottom, and certainly would not move up and down over the irregular surfaces of the sea bottom with as little change in direction as is indicated by the glacial striæ. Glaciers, however, are known to continue their courses with but little change in direction, especially where of large size and where crossing slopes of moderate degree compared with the thickness of the moving ice. Hence, the glacial origin of the striæ or scratches soon was admitted.

33. The Continental Character of the Glacier Reaching Southern Ohio

The average traveler is familiar only with glaciers confined to comparatively narrow areas, terminating usually within a comparatively small number of miles in some narrow valley. Such are the glaciers of the Alps, famous for their ready accessibility and picturesque surroundings. These are the glaciers of mountainous territories, originating at lofty altitudes and terminating at much lower levels. Owing to their mountainous origin they move down steep slopes and at comparatively rapid rates, considering the fact that glaciers are composed of material as rigid as ice.



Diagrammatic representation of successive positions of the ice border during the melting back of the continental glacier. The general direction of motion of the glacial ice is indicated by the dotted lines and arrows. By Frank Leverett and Frank B. Taylor, 1910.

The conditions were very different with the continental glacier formerly covering almost all of the northern half of North America. It was of enormous proportions. The Labradorean, Keewatin, and Cordilleran ice sheets combined covered a total area of 4,000,000 square miles. From the central areas of dispersion, the Labradorean ice sheet extended 1,600 miles southwestward, as far as the southern parts of Illinois, while the

Keewatin ice sheet extended almost as far, 1,500 miles, to the central parts of Missouri. The only area of snow and ice at present in existence which can be compared with the continental ice sheet of former days is the Antarctic polar ice cap which also covers an area between three and four million square miles in extent. The next largest ice field still in existence is that which covers all of Greenland, excepting a narrow strip along the southwestern border. Its area has been estimated at 320,000 square miles. The largest glacier in Alaska, the Malaspina, covers an area 70 miles long, and between 20 and 25 miles wide, about as large as the state of Delaware. See map on page 76.

Even the lobes along the margin of the continental ice sheet were not confined along narrow valleys. The width of the Miami lobe, from Xenia on the east to Connersville on the west, was 60 miles. The width of the East-White river lobe, between Cambridge City on the east and a point beyond Indianapolis on the west, also approximates 60 miles. The Scioto lobe, on the contrary, between Urbana and Newark, attained a width of 80 miles. Numerous other lobes existed along the margin of the continental ice sheet, but these here cited are sufficient to indicate the enormous size of even the terminal lobes. See map on page 114.

Another great difference between the continental ice sheet and the Alpine glaciers is the comparative flatness of the territory over which most of the continental glacier moved. The center of dispersion of the Keewatin glacier is a low flat country, and yet from this center it moved from 800 to 1,000 miles westward, over what is now a westwardly rising plain, as far as the foothills of the Rockies. Although the center of dispersion of the Labradorean ice sheet lies on the Laurentide highlands, on the peninsula between Hudson bay and Labrador, nevertheless over a large part of its course, from the Ottawa river southwestward, it moved over comparatively flat country. South of the St. Lawrence basin and the Great Lakes the ice sheet also was obliged to rise, in order to pass over the watersheds limiting this basin southwards. In western Ohio, this water shed rises about 600 feet above the present level of Lake Erie, a shallow lake with an average depth of about 100 feet. Therefore the basal parts of the ice sheet were obliged to rise at least 700 feet, south of Lake Erie, before reaching the lands sloping toward the Ohio river.

34. The Thickness of the Ice Sheet and the Slope of Its Upper Surface

The outward flow of the ice sheet from its centers of dispersion was determined much more by the amount of slope of the upper surface of the ice sheet than by the slope of the underlying land. There was a continual pressure from the areas in which the surface of the ice sheet attained the higher levels toward the areas where these surface levels were lower. In general, it may be assumed that the ice sheet was thickest where its surface attained the greatest elevation, but the point to be emphasized is that the flow of the ice was not so much from the point where it was thickest to the point where it was thinnest, as it was from the point of higher elevation toward the point of lower elevation. A thinner mass of ice at a higher elevation might force along a thicker mass of ice at a lower elevation, and in the last analysis the elevation of most importance is that along the upper surface of the ice, and not that along its basal portion.

On this account it would be interesting to know something about the former slope of the surface of the continental ice sheet. However, little is known. The greatest slope of the surface of the ice sheet probably was near its margin, where it was more or less rapidly melting away. At the edge of the ice sheet, near Baraboo, Wisconsin, where the ice moved along the side of a bold ridge, the average slope for the last one and three-fourths miles was 320 feet per mile, or a total of 560 feet in the entire distance. Several miles from the edge of the ice sheet, in certain parts of New Jersey and the adjacent parts of New York, the rate of slope of the upper surface of the ice was about 30 feet per mile. From these data, a thickness of 1,000 feet at a distance of 10 miles back from the ice front might be considered a moderate estimate. Farther back from the ice margin the slope of the upper surface of the ice sheet probably was less than 30 feet per mile, but even at the rate of 10 feet per mile the thickness of the ice sheet at its center of dispersion may have exceeded two and a half miles. Even if this number should prove excessive, there is no doubt about the great thickness of the former continental ice sheet northward.

35. Rate of Motion of Glacial Ice

The most rapid rate of motion observed by Tyndall along the middle of one of the largest valley glaciers in the Alps, known as the Mer de Glace, was about three feet per day. The Muir glacier, in Alaska, has a rate of motion of about seven feet per day. Both of these glaciers have steep descents. Where some of the glaciers of Greenland crowd into a narrow valley with a steep descent the rate of motion during summer time may exceed even 50 feet per day. On comparatively flat surfaces, during winter time, the rate of motion may be much slower. The average rate of motion of the inland ice of Greenland, during winter time and away from the areas of steep descent, is stated to be probably less than a foot per week.

It is probable that the rate of motion of the ice forming the continental ice sheet, during winter and away from the ice front, was comparable with this smallest number. At the margin, where the slope of the upper surface of the ice sheet was greatest, the rate of motion may have equalled one foot per day, or even more, locally.

36. Cause of Motion of Glacial Ice

Glacial ice does not move like a fluid, not even like a viscous fluid. When tar, under the influence of the heat of the sun, creeps down an inclined surface, it does not push any loose rock ahead of it, but flows over the rock and envelops it. Lava, in the same manner, does not push objects in front of it forward, but flows over them. Glacial ice, on the contrary, is rigid, and is pushed forward bodily. The rock embedded within the glacial ice is held rigidly and may be pushed forward like an engraving tool. The rigidity of ice is shown by the readiness with which it breaks or separates at crevasses, where it changes its direction of flow or drops down to some lower level along its path.

While a downward slope of the land surface over which a glacier moves undoubtedly accelerates its rate of motion, it is evident, nevertheless, that this downward slope is not the sole factor determining the direction of flow of the ice. It has been noted already that the Keewatin ice sheet moved from a low-lying territory, along Hudson bay, westward for a distance of 800 to 1,000 miles along rising land toward the foot hills of the northern Rockies. In the same manner the Labradorean ice sheet moved from the valley of the St. Lawrence toward higher territory on approaching or crossing the present watersheds, southward. On the western slope of the Alleghanies, in northwestern Pennsylvania, the southern margin of the Labradorean ice sheet attained altitudes of nearly 2,000 feet above sea level, rising fully 1,400 feet above the present level of Lake Erie.

From this it may be seen that the ice moved as though thrust forward by some enormous force. This must have been a force acting not only in summer, but also in winter, although in winter the rate of motion of glacial ice is much retarded.

As already indicated on one of the preceding pages, this force probably was due to the difference in pressure produced by differences in level of the upper surface of enormous thicknesses of ice. This corresponded to the difference in pressure causing a flow in water from a point of higher level toward a point of lower elevation.

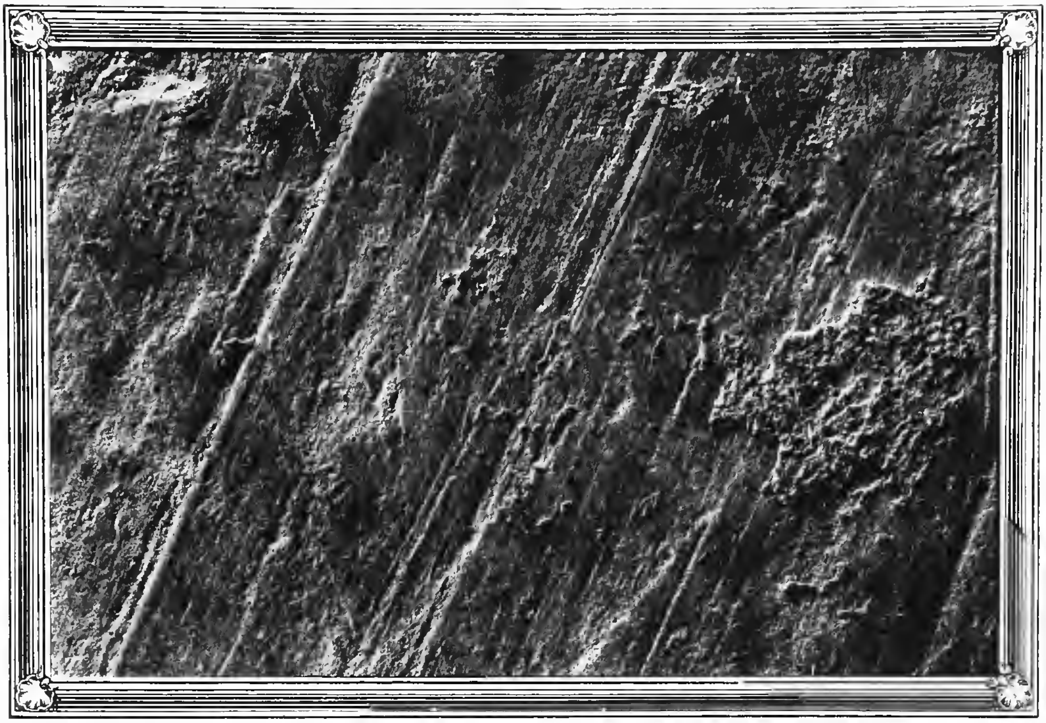
In order to account for the forward flow of such a rigid material as ice an ingenious theory has been invented which will appeal more readily to the student of physics than to the general reader. According to this theory the snow flakes, from which all glaciers start, sooner or later, under the influences of the sun, turn into granules of ice, somewhat like the granules of ice forming the crust on snow in winter time in our own climate. The accumulations of many snow falls interrupted by many days of sunshine result in the heaping up of enormous quantities of these ice granules, which, owing to their combined weight, tend to produce great pressure upon the bottom layers and to force them away. The looser ice granules actually may be pushed onward, to points of less pressure, which usually means down a valley, but those ice granules which adhered more firmly to their neighbors could be moved only by giving way at their points of contact. As is well known to students of physics, ice under pressure tends to melt, and if the melted water moves merely into some neighboring crevice, without being raised in temperature, it instantly freezes again. This is owing to the fact that pressure lowers the melting point of ice, and release of pressure permits refreezing.

Under these conditions, the pressure of the overlying weight of ice granules continually melts parts of the granules of ice at their points of contact, permitting an onward motion, the resulting water freezing in the intermediate spaces between the granules and adding to the rate of onward motion of the ice granules by the thrust produced by the expansion of the freezing water. The force of expanding ice during the freezing of water frequently is illustrated by the breaking of pitchers in winter.

Farther down the slope, where the ice granules have become more or less intergrown, the expanding force of freezing water, released by pressure at one point and expanding within a neighboring crevice, may be the chief factor in keeping up a continual thrust within the ice. Since this melting of the ice granules is due chiefly to pressure, at least when far below the surface of the glacier, it may take place not only in summer, but also in winter. This accounts in part for the streams of water which issue from beneath glaciers in great volume even during the coldest days of winter.

According to this theory, continual melting at one point of contact between ice granules and refreezing in a crevice at another point only a minute distance away may take place at great distances from the center of dispersion of a glacial ice sheet. Indeed, it has been suggested that the points of *maximum* thrust may be a considerable distance away from any one of these *centers* of dispersion.

While the force of expansion of the freezing water within any one of the minute crevices in the ice may not seem great, the accumulative effect of freezing water in countless numbers of these minute crevices over immense areas might be enormous; in fact, might be sufficient to account for the motion of glacial ice. This motion might be much accelerated by the presence of steep slopes, warm temperatures, an abundance of water, and of other factors, but the prime cause of motion would still be the melting of ice and the freezing of water where subjected to pressure and then released from the latter. Such a thrust due to freezing water might even force the margin of an ice sheet up to higher elevations, in opposition to the laws of gravity.



Surface of Dayton limestone, in the Soldiers' Home quarry, marked by glacial striæ running S 35 E.

CHAPTER VI

THE DEPOSITS LEFT BY THE GLACIAL ICE SHEET

37. The Graving Tools of Glaciers

The rocks embedded in the bottom layers of the ice could serve as graving tools only if held rigidly by the moving ice. It is known that ice free of rock has very little effect in moving over a smooth surface. Moreover, wet or warm ice does not hold rock firmly, but tends to permit it to rotate readily where in contact with the underlying surface. Rock is held rigidly only where the surrounding ice is cold and dry. Hence the scoring or smoothing action of moving ice should be greater during winter and at some distance back from the melting ice front.

The bottom of the ice sheet is debris laden. It is liable to contain fragments of all the rock over which it has passed. By the slipping of rear layers of ice over those in front, in crossing some valley or descending some hill, the lower parts of an ice sheet usually become rock laden for some considerable distance above its base.

It is a curious anomaly that the lower parts of a glacier may become so filled with rock that it no longer serves well as a graver of the underlying rock surface. Owing to the great quantity of rock fragments in the ice, the relative quantity of the enclosing ice may be reduced to such an extent that it no longer serves as a good binding material, and therefore fails to hold the enclosed rock rigidly. The principle is about the same as using too much sand and gravel and too little cement in mixing up concrete. Hence the bottom of an ice sheet enclosing too great an amount of debris may do very little scoring of the underlying rock surface. This probably accounts for the fact that glacial scratches are not more commonly found on rock surfaces on removing the overlying debris. Sometimes glacial

Glacial boulders of Canadian granitic rocks.

scratches are absent over wide areas where the character of the rock surface is favorable to their retention.

It is probable that in some cases the rock-laden bottom of the ice sheet was so loosely held that it was thrust forward but very little by the overlying ice sheet, the latter over-riding its debris-laden base, and, at times, passing even over sand and gravel deposits without greatly disturbing their stratification.

38. Boulder Clay or Till Produced by the Grinding Action of the Moving Ice Sheet

In the process of smoothing the underlying surfaces of the rock, the glaciers reduced much of the ground-off material to powder. This powder, together with the great quantity of angular rock fragments still remaining, was continually carried southward, enclosed in the ice, by the forward motion of the glacier. This powder forms the clay, blue or brown in color, which locally rests upon the upper surface of the smoothed-off rock. When moist, this clay locally becomes very sticky. It is difficult to dig through it with a pick. The pick penetrates only a short distance and then is liable to stick so that it can not be pulled out readily. Hence the clay often is known as hard-pan, especially among well diggers. The scientific name for the entire mixture of clay and broken rock is till. Till, in fact, is the proper name for any rock debris left behind by a melting glacier. Since this till usually contains numerous rock fragments, it is known also as boulder clay. When boulder clay becomes dry under the influence of sunlight, it frequently becomes very hard.

Boulder clay may be recognized, when in large masses, by the entire absence of arrangement in layers. The rocks occur irregularly distributed throughout the mass of clay. Large fragments are intermingled with small ones, and both are more or less angular in form. This angularity of the fragments and absence of arrangement in layers is due to the fact that the boulder clay was not deposited by water, but was transported by ice.

Originally, the bottom part of this till must have been more or less in contact with the underlying rock, at least along part of its course. The larger part of the till however, must have been more or less embedded in the lower part of the ice sheet. When the ice melted, the till dropped. Such enormous quantities of till were included in some parts of the ice that the till left behind formed a thick deposit or covering over the underlying rock.

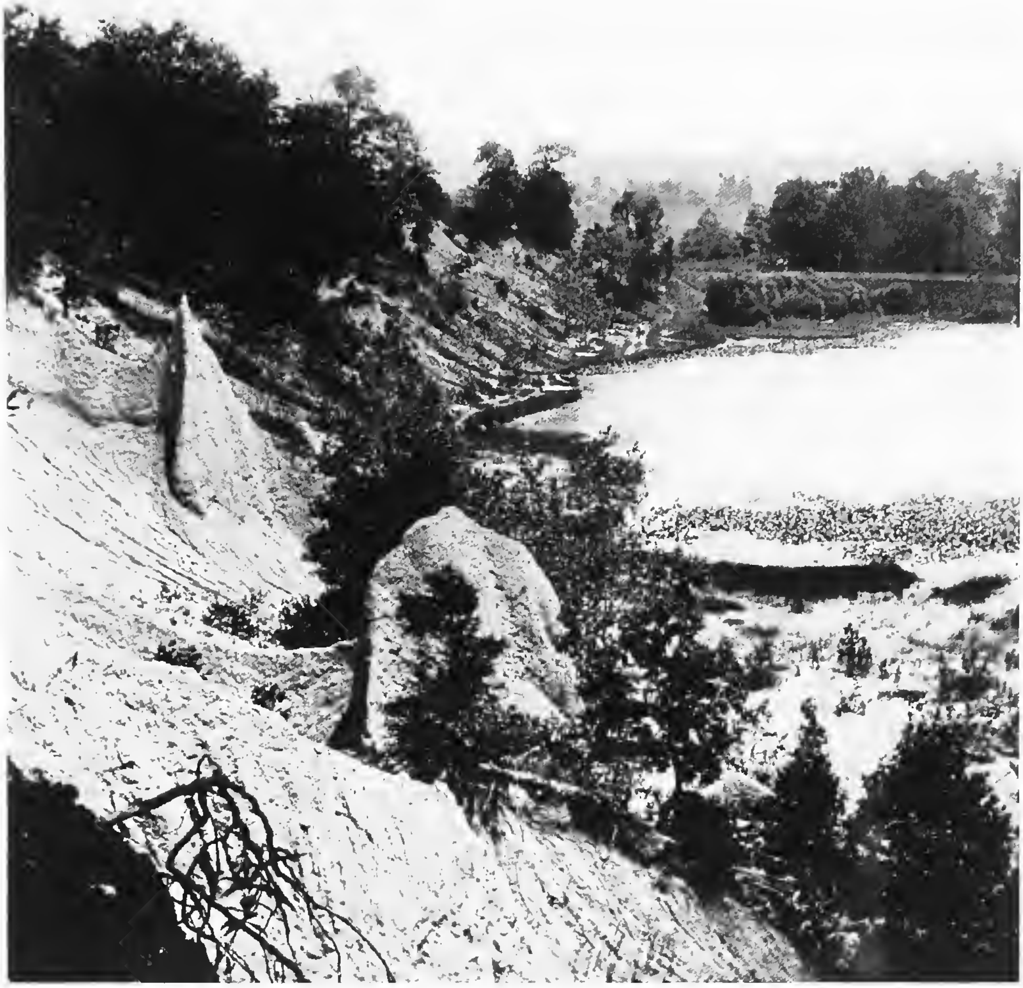
The rocks within the till are the implements with which the moving glaciers ground the underlying rock surface. Frequently these rocks indicate their former use as grinding tools by being more or less smoothed and striated themselves. Frequently they present flattened surfaces indicating that the rock fragments had been held more or less rigidly for some time while being dragged by the ice over the underlying rock. Even those fragments which occur far above the base of the till deposit often show strong striation and flattening, showing that they once were included in the basal parts of the ice sheet, but were forced upward, probably by the sliding of different parts of the basal layers over each other, those from the rear sliding over those farther toward the front, locally. In this manner the till gradually worked its way farther up into the lower parts of the ice sheet, which evidently in some areas must have been heavily charged with till for a considerable distance above the base.

In a similar manner, the ice sheet, near its margin, often was pushed over sand and gravel layers, leaving till deposits far above the striated rock surfaces beneath, and separated from the latter by considerable thickness of water-transported materials. In fact, near the margins of the ice sheet, the till and sand or gravel may be more or less interbedded.

39. Till Deposits in the Vicinity of Dayton

Numerous till deposits occur in the vicinity of Dayton and some of these are of considerable thickness. They may be recognized by the abundance of clay, often very hard where exposed to the sun, usually enclosing angular fragments of rocks, irregularly distributed throughout the clay mass.

One of the best known deposits of till is that at the Pinnacles, about a mile northwest of Alexandersville, on the north side of the great bend in the Miami river. Here a vertical height of 80 feet of till is exposed. For-



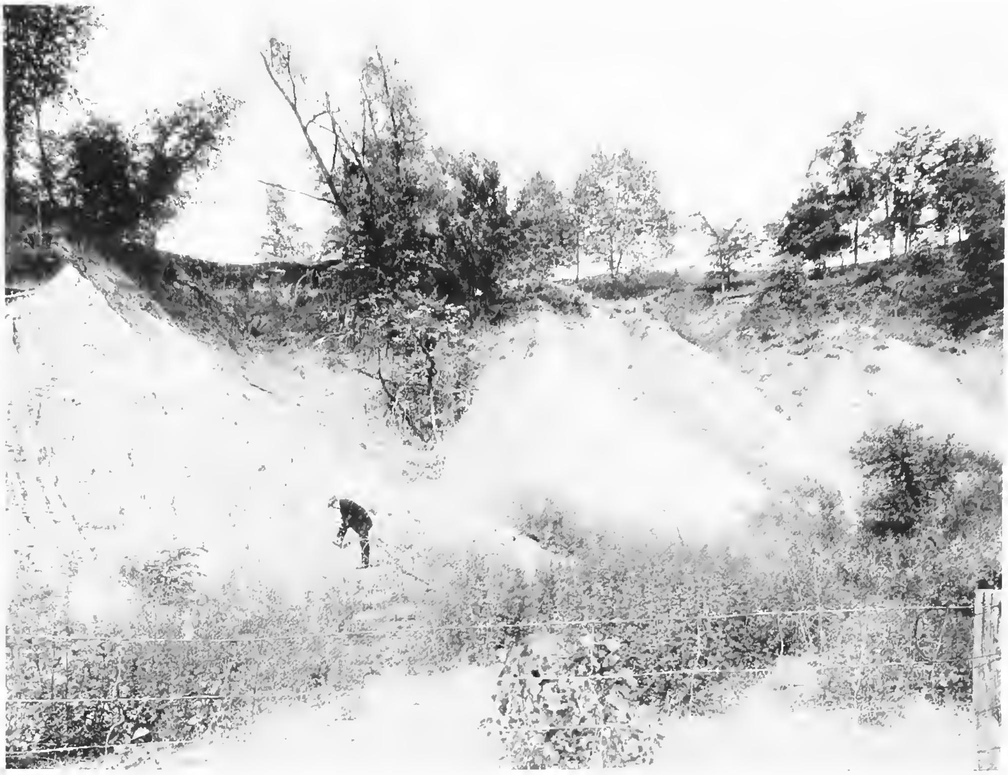
The Pinnacles, four miles southwest of Dayton, west of the Miami river, seen from the west. An enormous till deposit, formerly washed at its base by the Miami river, but protected for many years by the embankment followed by the C. H. and D. railroad. The imponded waters back of the embankment are shown on the right. The exposed surface of till has been strongly gullied and ridged. In the immediate foreground one of the ridges ends in a tall wedge-shaped mass. A short distance farther back another ridge ends in a sharply pointed pinnacle. Photographed in 1895.

merly this till was deeply gullied by the wash of rains, and the intermediate parts were left as sharp ridges. Thirty years ago, the terminal parts of several of these ridges rose into acute peaks, which could be ascended only by straddling the sharp ridges at points farther back, and then gradually working forward toward the peak. At that time the name Pinnacles was a very appropriate term for this great till exposure. It was a favorite picnic resort, and an abundance of wild flowers could be secured in the lowland surrounding the pond, and in the narrow valleys among the surrounding hills. This is the only locality near Dayton where the yellow blossoms of the witchhazel may be found in October, after the leaves begin to fall. It forms a large sized shrub or small tree, and its habit of beginning to blossom in the very late fall may be of very recent origin, as geologists reckon time, since the structure of the flower bud is that of a spring blossoming plant.

Northward from the Pinnacles, the till may be traced toward the Soldiers' home. It underlies most of Dayton View. Since it is quite impervious to water, cellars filled with water after a heavy rain remain damp for a very long time, as many an inhabitant of this suburb, whose home is not connected with the city sewers, will admit. Till frequently is exposed here in digging foundations for buildings. Till forms most of the hill land west of Forest avenue, and it was struck within 6 feet of the road level in digging a sewer at the southern end of this avenue.

In digging the pits for the abutments of the Main Street bridge, this till formed the considerable thickness of "hard-pan" which the workmen found so difficult to remove.

South of the Pinnacles, till may be traced to Germantown. One mile east of Germantown, south of the great bend in the traction line, where Twin creek assumes a southerly course, the till deposits have a thickness of at least 70 feet, down to the level of the creek. These deposits have become quite famous since they include at the base a thin layer of peaty soil containing cedar berries, fragments of wood from some evergreen or coniferous tree, mosses, grasses and sedges, which must have lived before the advent of that part of the ice sheet which left the overlying till. These plant remains evidently are a remnant of a flora living thousands of years ago. In a similar deposit near Wilmington, Ohio, Doctor George M. Austin found the hard parts of beetles. In fact, sufficient plant and animal remains have been found in the glacial deposits in different parts of the world to give us some clue as to former climatic conditions. These were, of course, colder than those existing at the present day.



Till deposit at the bend of Hole's creek, north of the bridge on the Bellbrook road, two miles east of Alexandersville. This till deposit occurs west of the southern end of the Walden gravel ridge and formerly was connected across Hole's creek with the great till deposits covering the hill fronts on the southern side of this creek.

Another great till deposit is located along Hole's creek, about 2 miles east of Alexandersville. It may be reached by following the western outlines of the hills southward for a distance of about a mile from the Delco Dell. Here the northern margin of the creek is cutting at the base of a steep wash of the hill slope. Almost the entire exposed face of the hill consists of till. At a considerable distance above the creek, this till is overlaid by a continuation of those sands and gravels which, farther north, form the gravel ridges of Delco Dell and the Moraine farm.

It is probable that till underlies the entire gravel ridge area north of the Moraine farm as far as the bluffs at the Calvary cemetery and the hills east of Carrmonte.

At the gravel pit worked by the Washed Gravel and Sand Company, along the northwestern margin of the Calvary cemetery, till is exposed between 22 and 25 feet above the level of the canal, and appears to be abundant up to a level of 40 feet above the canal. It probably extends far below this level, but there is no exposure at present at any lower level in this vicinity.

Till, however, is not confined to any particular level. Since the glacial ice moved both up and down hill, there is a possibility of till occurring wherever the ice has been. Since the ice sheet in the vicinity of Dayton moved in a direction about S 30 degrees E, it is evident that, after crossing the Miami valley in the southwestern part of Dayton, it would push up against the hills on the southeastern side of this valley. In early geological times, before the gravel ridges in the area between Carrmonte, Hills and Dales, Moraine farm and Delco Dell had been formed, the eastern side of the Miami valley was formed not by the high land now stretching southward from Calvary cemetery to the Grand View farm, south of the Stroop farm and west of Delco Dell, but by the high territory extending north and south along the Lebanon pike, more than a mile east of the Delco Dell. Along this eastern margin of the ancient Miami valley, the advancing ice sheet plastered the hill slope with till, a part of this till rising considerably above the level of the till in the gravel pit northwest of the Calvary cemetery.

Nothing but till was struck in digging the cellar and boring the first well at the residence of Doctor Scheibenzuber, south of the Frederick farm, half a mile north of the Stroop road, on the western side of the Lebanon pike. The first well here was bored to a depth of 180 feet without striking anything but till. Nothing but till was struck in digging a trench southward from the residence toward the small stream at the foot of the hill slope. Westward, however, the overlying gravels come in. The structure, here, is that of a till sheet rising toward the ancient hill surface eastward, covered by a great mass of gravel and sand, thick westward, but thinning out eastward, on approaching this same hill surface. The top of the till at the Scheibenzuber residence attains an elevation of 1,000 feet above sea level, while at the gravel pit northwest of the Calvary cemetery the top of the main mass of till is only about 780 feet above sea level, but even the latter is far above the rock floor underlying the sands and gravels now filling the river valley.

Till underlies most of the hill surface east of the Lebanon pike, as far north as Beavertown and thence toward Huffman hill.

At the quarries northeast of Beavertown, now abandoned, the following observations were made by Frank Leverett, about 15 years ago.

"A good exposure of the structure of nearly plane-surfaced upland drift appears at the Beavertown quarries 3 to 4 miles southeast of Dayton. There is being removed here about 20 feet of drift, consisting of an almost continuous capping of yellow till 5 to 10 feet in thickness, beneath which are deposits of poorly assorted gravel and sand horizontally bedded. In places these gravelly deposits reach to the (underlying Dayton) limestone, but fully as often a thin bed of till intervenes. The surface of this lower till is uneven, and the gravel rests unconformably upon it. The lower beds of gravel being horizontal, are shut off where the till rises above their level. This break between the lower till and the overlying deposits may indicate a lapse of considerable time between their deposition, though it is not known but that the erosion of the surface of the lower till was rapidly accomplished by the same streams which deposited the overlying gravel and sand."

Thirty years ago I was much interested in digging out of this lower till deposit fragments of wood, often two inches in diameter and 12 to 15 inches long. The wood came out of the till in good condition, but, on drying, it cracked considerably, especially lengthwise, and separated also into layers, parallel to the rings of growth. This wood evidently consisted of remnants of some coniferous or evergreen tree. At that time we were in the habit of calling them cedar, but no microscopical examination of the wood ever was made, and hence their exact identity can not be considered as established. They may have been fragments of tamarac or of some other coniferous tree. Possibly they were obtained from trees growing not far north of Dayton, since during the ice age many plants must have existed at Dayton which under present conditions would not be expected south of Ontario.

Another instance of till plastered against a hill front on the eastern side of the Miami valley is shown in the northeastern part of Ohmer Park. Here a small country schoolhouse has been located for many years about two squares east of the corner of Wyoming and Arbor streets. Several squares north of this school, near the western prolongation of Alice street, and within easy reach from the Wyoming street car line, a gravel pit, 35 feet deep, is located. It is on the western side of a narrow valley. This valley formerly was ascended by the mule railroad, extending from central Dayton southeastward to the now long abandoned Dayton limestone quarries along the Smithville road. The right of way for this railroad passed north of the schoolhouse already mentioned, and still may be traced back toward Dayton as far westward as the northward prolongation of Carlisle street, about half way between Tacoma and Wyoming streets.

The gravel pit, south of the schoolhouse, is run by Paul Nill and C. H. Delaplane. Its base rests upon the top of a great sheet of till. At this locality the till consists of blue clay, almost free from rock. It evidently was deposited under peculiar conditions, since the clay tends to crack horizontally, as though deposited under the influence of water action. Southeast of the gravel pit, up a narrow gully, the blue clay rises to higher levels than at the bottom of the gravel pit, as though plastered against the hillside southeastward.

Till probably underlies a great part of the territory in the vicinity of Dayton, even where it is not exposed. In the territory covered by the gravel ridges, south of Dayton, its presence is concealed by the covering of sand and gravel.

39A. The Well at Delco Dell

In 1913 a well was drilled by Ira W. Barnes on the side of the hill at Delco Dell.

Beginning at the surface of the earth the well passed in succession through two feet of loam, 10 feet of clay, 15 feet of gravel, 50 feet of fine sand, 90 feet of hard-pan, 2 feet of gravel, 15 feet of clay, some kind of blue rock 2 feet in thickness, 14 feet of dark blue clay, and finally 37 feet of clay which was a real dark purple, with some shale, toward the top and which changed to a light pea green below. The total depth of the well was 237 feet.

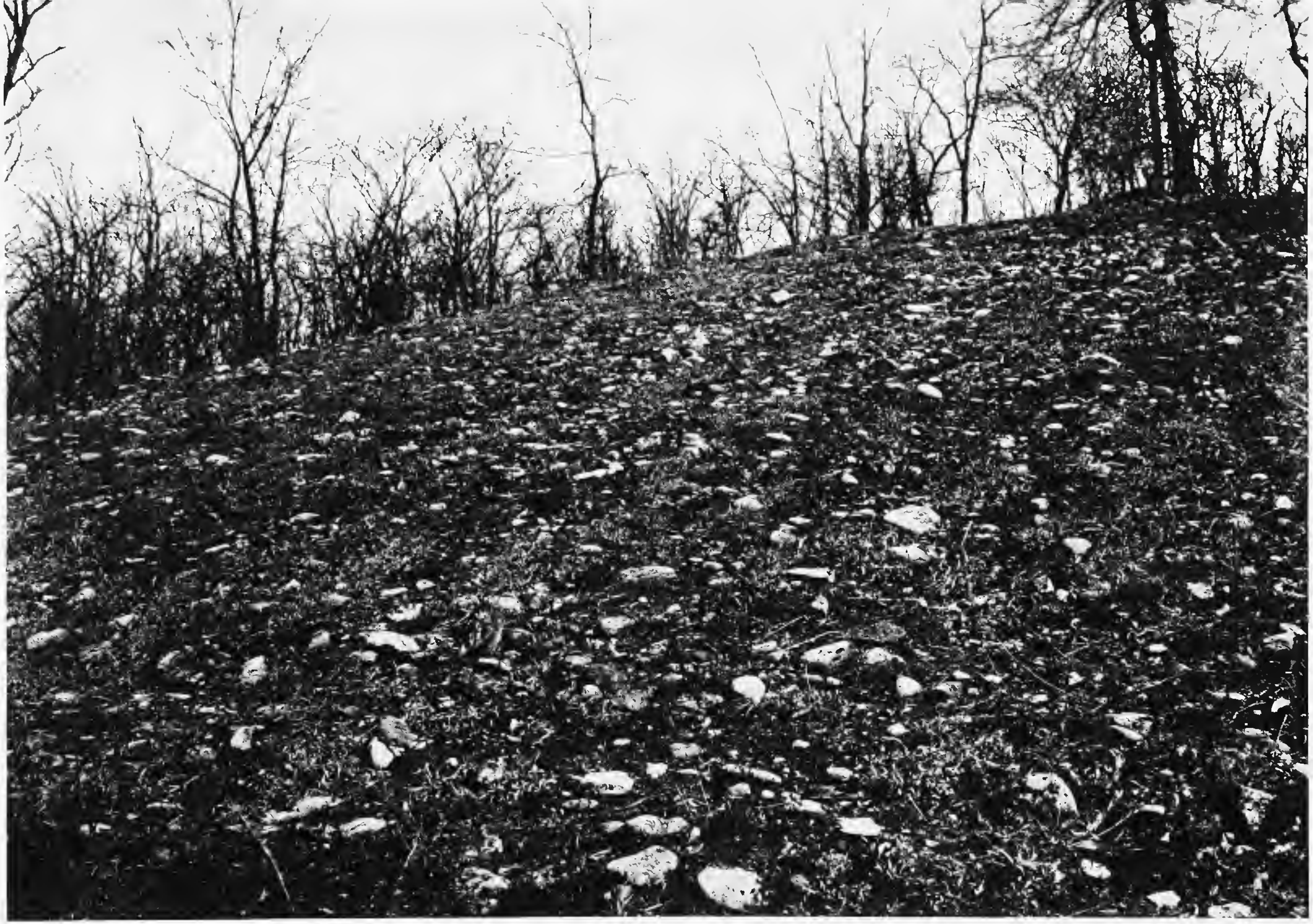
The expression hard-pan, used by the well driller, almost invariably means till. According to this observation 77 feet of soil, gravel, and sand here overlie a great thickness of till deposits. The fragments of rock shown me from the 184-foot level consisted of glaciated pebbles from a till deposit. The till deposit evidently was continuous from the 77-foot level down to the 200-foot level below the top of the well. This gives an estimate of at least 123 feet for the thickness of the till penetrated by the well. It is not worth while attempting to determine the character of the light pea green clay material, without seeing a sample. It may still belong to the till section. If it formed part of the basal Richmond or upper Maysville section of rocks there should have been evidence of the presence of some limestone, though only in comparatively thin courses. The apparent absence of such limestone fragments suggests that at the bottom of the well the boring was still in the till, the underlying rock not having been reached.

It is quite evident that it is useless to search in this immediate area for water below any level which is on a horizontal line with this level of 77 feet below the top of the Barnes well at Delco Dell. Till is never a water carrier, although immediately above the till water may be expected in abundance locally.

Eastward, toward the Doctor Scheibenzuber farm, the level of the top of the till evidently rises, although probably in a very irregular manner. Westward the top may descend to still lower levels.

40. The Material Carried Forward Within the Ice Sheet Forms the Ground Moraine

The material carried forward by a glacier and left behind after the melting of the ice forms the moraine. In mountainous areas a large part of this material may consist of rock dislodged from the overhanging cliffs and may be carried on top of the ice. Tyndall describes in a very interesting manner the continual rain of rocks falling from the mountain heights



PEBBLES eight to twelve inches in diameter exposed by the removal of the soil following the deforesting of the land, on the western slope of the Pike ridge, just south of the Sub-power station, south of the O'Neil road. Photographed by Prof. J. L. Lambert. Any attempt to farm this land soon results in the removal of the soil. This land is suitable only for forestry or grazing on the upper surface of a glacier whose rate of flow he desired to measure. So numerous were the fragments that the surveyor at times found difficulty in keeping his instrument in position long enough to accomplish his work.

In the case of continental ice sheets very little rock could have been carried on the surface, and that only within comparatively short distances from the cliffs from which they fell. Sooner or later these fragments of rock drop from the surface into the crevices which open where the ice changes its direction of flow or drops to some lower level or passes over an obstruction. At some point farther on, the pressure of the ice shoving from behind may close the crevices again, and then any rock which has fallen into a crevice not extending down to the bottom of the ice sheet becomes *englacial*, or is embedded in the ice.

Evidently most rock carried along by a continental ice sheet must be embedded within its basal parts, having been picked up by ice from the *underlying* rock over which the ice sheet passes. Owing to the sliding of the basal layers of the ice sheet over each other the lower part of the sheet becomes charged with rock for a considerable distance above its base. Sometimes this rock is so abundant, especially near the end and at the sides of a glacier, that it is difficult to determine where to draw the line between the bottom of the glacier and the underlying deposit of more or less loose rock fragments.

That part of the moraine which was carried along chiefly embedded within the lower part of the ice sheet, and which was left behind by the melting of the ice sheet, forms the ground moraine. At any considerable distance back from the ice front this ground moraine consists chiefly of broken rock and clay—the mixture called till. Nearer the margin of the ice sheet, the melting waters might give rise to streams running along channels underneath the ice, and these might wash away the clay and round the rock fragments into gravel and sand.

The melting of the ice sheet at its margin not only releases the rock embedded within its lower parts, but also allows the englacial rock, far above its base, to drop, and this rests upon the ground moraine or is embedded within its upper part. Since this englacial rock has suffered little wear since falling on the ice, it is likely to consist in part of large and only moderately rounded boulders.

41. The Shifting of the Front of the Ice Sheet

A continental glacier moving southward sooner or later must reach a climate sufficiently warm to cause the ice to melt. Melting, of course, tends to decrease the distance to which the ice may spread from the center of dispersion.

If the rate at which the ice melts back at its front margin exactly equals the rate at which the ice itself moves forward, the front of the ice sheet appears stationary. If melting takes place at a more rapid rate, the front of the ice sheet appears to retreat. If less rapidly, the front of the ice sheet advances. Evidently, under all three conditions, whether the front of the ice appears to be stationary, retreating, or advancing, the ice itself actually is moving forward.

All three conditions may exist during the same year, but at different seasons. In summer, the front may be retreating. In winter, it may be advancing, and during parts of spring and fall it may be stationary. However, it is chiefly the accumulated effects of all the changes during a series of years which prove interesting. A preponderance of forward motions during a number of years might result in the ice front moving forward a distance of several miles; or a corresponding series of apparent backward motions might result in a considerable retreat of the ice front.

Changes of this kind suggest a change of climatic conditions, such as often are discussed by the weatherwise. In reality, however, supposed climatic changes usually tend to balance each other. A series of warmer years usually is followed by a corresponding series of colder years, the general average for a long period of years remaining the same, so that it is not safe to assume that any more permanent change of weather conditions has taken place unless the records cover many years. Similar changes of climate, but on a larger scale, unquestionably took place during the long lapse of time covered by the so-called glacial period.

42. *The Terminal Moraine*

The ice sheet, of course, could not carry the rock embedded within it farther forward than the ice itself moved. This is so obvious that it requires no further comment. But what became of the embedded rock and clay? Naturally, it would remain at the most southern point to which it had been carried before the ice melted, unless moved still farther onward by some stream or other agency.

It is evident that if the ice sheet, in moving southward, for a period of many years reached approximately the same point before its advance was halted by melting,—in other words, if the ice front remained approximately stationary,—a great quantity of rock and clay would accumulate along its margin. This accumulation would include not only the till embedded within the lower part of the glacial ice, but also any englacial or superglacial rock carried along by the middle or upper parts of the ice sheet. Such an accumulation of till and englacial rock along the front margin of a glacier is known as a terminal moraine.

Terminal moraines at the bottom of glaciers occupying narrow valleys sometimes are so distinctly defined that they appear almost like transverse ridges halting the further advance of the ice. Such distinctly defined terminal moraines are exceptional and probably mark accumulations of no great number of years at the base of glaciers charged to an unusual degree with rock fragments and rock powder or clay.

The terminal moraines of the ancient continental glacial ice sheets rarely are so distinctly defined. Frequently they spread over a width of two miles and rise only from 40 to 80 feet above the general surface of the land. Such a low and broad elevation, especially where the upper surface is irregular, can not be recognized by the average observer as a ridge, and hence must be identified by the student who recognizes the morainal character of the deposit by means of the material of which it is composed and by carefully mapping its distribution with reference to other deposits.

It is evident that, compared with the moraines of Alpine valleys, the terminal moraines of continental glaciers must represent much slower rates of accumulation of rock and clay, due to the much slower rates of motion of the glacial ice over much flatter territories. During the much longer periods of accumulation the ice front probably shifted forward and backward repeatedly, frequently over-riding earlier accumulations and smoothing out steep slopes by addition or removal of material, so that the average topography of the terminal moraine of a continental glacier is not sharply defined.

43. The Melting of the Ice Sheet

The melting of the ice sheet, of course, was not confined to the margin of the ice sheet. Glacial climate probably was only moderately colder than our present climate. It has been estimated that a lowering of the average annual temperature less than ten degrees would be sufficient to account for the former widespread glacial conditions. Apparently the colder climatic zones of the earth had shifted southward, toward the equator, but there is no evidence of excessive low temperatures. During the warm season of the year the ice must have been melting everywhere, even at its centers of distribution. Under the influence of the sun, melting must have taken place over wide areas also in winter.

Attention has been called already to the streams issuing from beneath the margins of glaciers even during the coldest days of winter. Evidently the lower parts of the ice sheet melt continually, owing to the pressure of the enormous amounts of overlying ice.

Evaporation probably also played an important part in the thinning of the ice sheet as it progressed southward. Even in the solid state ice evaporates considerably as is shown by wet clothing hung out to dry in freezing weather, and evaporation must have been rapid in warmer weather when the upper layers of the ice were soggy with water.

The most rapid melting, of course, must have taken place near the margin of the ice sheet. Here enormous quantities of water must have been released, forming many streams carrying rock, sand, and mud forward from the ice front.

44. Subglacial Streams and the Formation of Eskers

Sooner or later the water formed at the surface of the ice sheet, by melting, finds its way into crevices, and either is absorbed by the ice or finds its way down to the lowest depths, where it joins the water produced by the melting of the basal parts of the ice, owing to pressure, as explained in the preceding lines. These may be called the *subglacial* waters or those which exist beneath the ice sheet. They frequently flow along distinct channels, and form *subglacial* streams. Where they issue from beneath the ice sheet, at its margin, they may be of large size, as is the case of the Rhone, which is already a stream of considerable size where it appears from beneath the Rhone glacier.

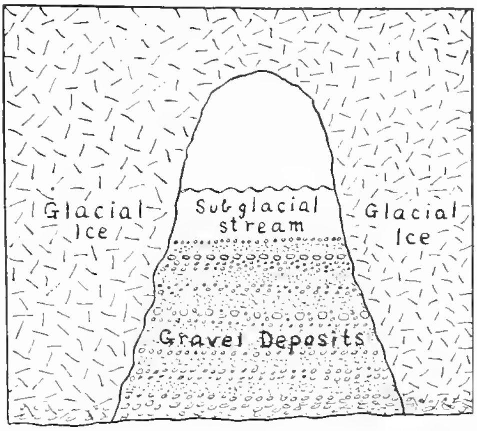
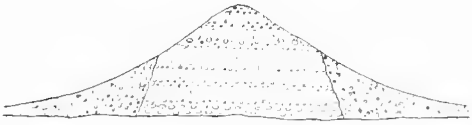


Diagram representing gravel and sand deposits left by a sub-glacial stream. The deposits, of course, are much more irregular than here indicated. The top of the glacial ice must be imagined as far above the highest part represented in the diagram.



A gravel ridge or esker formed by the slumping of the upper part of the gravel and sand deposit, left by the sub-glacial stream, after the melting of the ice. In this diagram the slumped part of the deposits are shown as having lost all evidence of bedding or arrangement in more or less distinct layers. In nature, part of the slumped material might retain evidences of former bedding.

Where subglacial streams flowed along confined channels, the waters must have flowed with great velocity. Such streams must have been charged heavily with rock and sand and mud from the melting base of the glacier, and the rock fragments must have been rounded and more or less sorted into layers, as in the case of ordinary streams, not flowing beneath glacial ice.

Where the subglacial streams occupied narrow channels, supported on the sides by steep walls of ice, the accumulations of gravel and sand along the stream channel may have been of moderate width compared with their total thickness. However, after the melting away of the lateral supporting walls, on the disappearance of the ice sheet, the lateral edges of the sand and gravel layers must have slumped off and rolled down, adding to the width of the deposit at its base, but permitting its top to become much narrower and more ridge like. In this manner, a deposit 100 feet wide at the top and 100 feet high might narrow to a width of 25 to 30 feet at the top and widen to more than 170 feet at the bottom. Such slumping could be detected best by a cross-section of the glacial stream deposit. The material which had rolled down the slope of the ridge toward its base would not be arranged in layers, but would lie in disorder against the lateral margins of those more central parts which still preserved evidence of arrangement in layers under the sorting action of running water.

Such narrow ridges of sand and gravel deposited by subglacial streams are known as eskers. They represent narrow stream deposits originally supported laterally by walls of ice. Eskers are phenomena chiefly of the extreme front of the ice sheet. Usually they are less than a mile long, but eskers scores of miles in length are known.

The long narrow gravel ridges south of Dayton extending from Calvary cemetery and Carrmonte southward to Moraine farm and Delco Dell, are eskers.

45. The Gravel Ridges South of Dayton Represent Stream Courses Beneath the Ice Sheet

From this point of view, the long narrow gravel ridges south of Dayton may be regarded as marking the location of former subglacial stream courses, or rather, of such parts of former stream courses as still are preserved. The subglacial streams, in general, flowed southward. Sometimes adjacent stream courses united, as in the case of the Nollman and Pike ridges, west of the Cincinnati pike. Here the depression crossed by the Nollman lane may be due to the increased swiftness of the waters at the point of junction of the streams. In the Hills and Dales, the Adirondack, Panorama and Watershed ridges unite near Inspiration point, in a region of high land in which the gravel and sand deposits form an almost continuous sheet.

46. Gravel Ridges Formed During Closing Stages of the Glacial Ice Age

Frequently the subglacial stream courses were united by short transverse channels. West of the Cincinnati pike, the Chapel and Pike ridges are united by the Nollman and Peters ridges. The Eastview and Sunset ridges are united at several points by short transverse ridges, the most conspicuous of which is at the Tip Top knob, at the southern end of the Old Orchard hollow, on the Moraine farm. Connecting ridges are seen also in the Delco Dell area. One of these is followed by the main road entering the grounds. It is probable that the spurs projecting westward from the Delco ridge, in the Delco Dell area, represent similar transverse channels connecting with a north and south ridge farther westward, of which only partial remnants remain. Short lateral spurs occur also on the western side of the Sunset ridge, northwest of the Summer camp, on the Moraine farm. Larger spurs occur on the Grand View Hill farm, southwest of the Delco Dell area.

The presence of these transverse ridges and short spurs suggests that the front of the ice sheet must have been very stagnant at the time of their formation. Moving ice would have shifted these lateral channels and would have spread their deposits over a wider territory. The ridge-like character of the deposits in these transverse channels would have been largely obscured.

Moving ice probably would have obscured also the sharpness of definition of the main gravel ridges, such as the narrow parts of the Pike and Chapel ridges, west of the Cincinnati pike, the northern part of the Adirondack ridge in the Delco Dell area, and the best defined parts of the ridges on the Moraine farm and in the Delco Dell area.

It is probable that the gravel ridges were formed during the closing stages of glacial action in this part of Ohio, when the ice front was melting back. There is no evidence that the ice sheet ever extended so far southward again. The deposition of the sands and gravels may have taken place in a very short time. Given an abundance of water and rapidly flowing streams, and a few years would account for all the gravel ridges seen south of Dayton. Under favorable conditions even a few months might suffice. At any rate, the formation of the gravel ridges probably was but a brief and minor episode in the long-continued glacial history of our continent.

Possibly the rapidity of accumulation of the gravel ridges accounts in part for the great variation in the heights attained at different points along

View of Cornfield hollow, looking north. This hollow lies west of the Lohman ridge. This is an excellent illustration of the frequent occurrence of low depressed areas, without drainage outlets, between the parallel gravel ridges.

their crests. Deposition, in general, is an evidence of arrested, or at least, diminished transporting power. At the most rapid points of flow, the sand and gravel would be carried off; at the less rapid points they might remain. It is the points of more rapid flow that give rise to the swimming pools along streams.

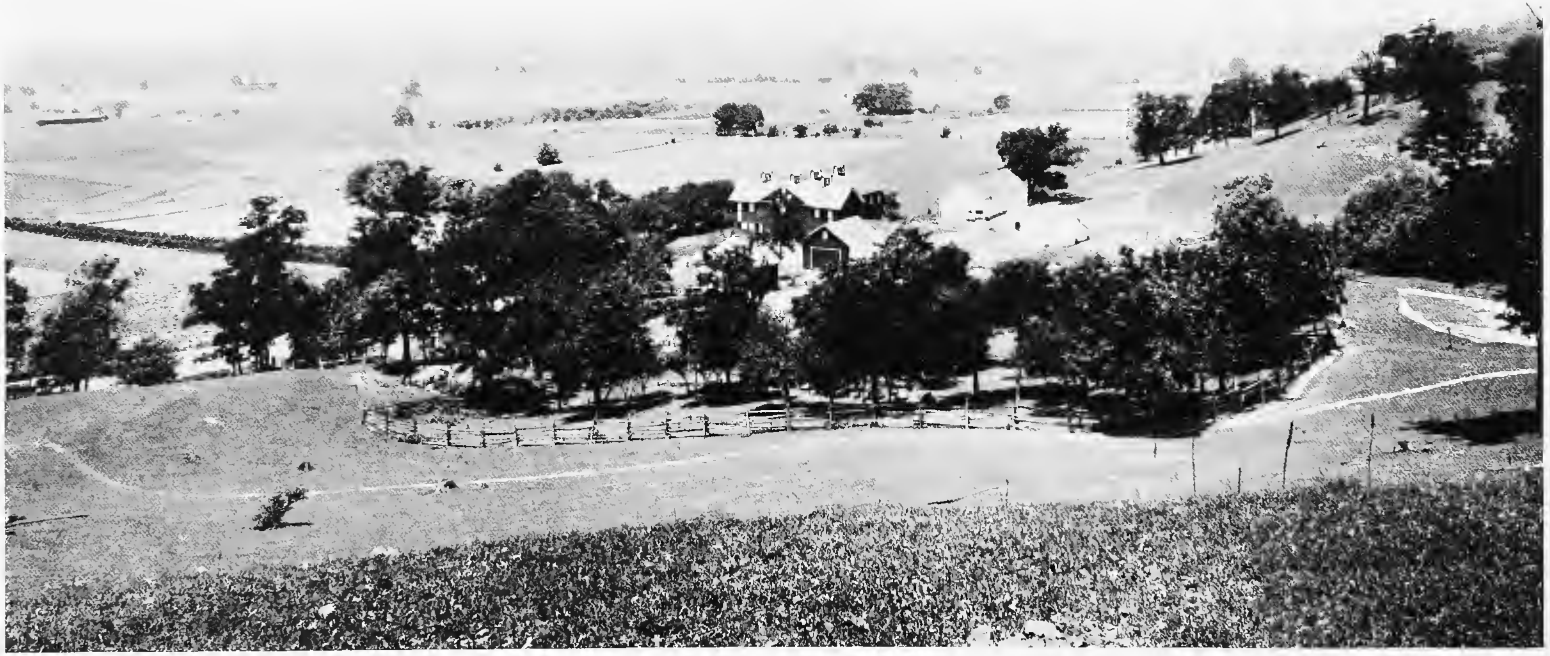
47. The Kame Area

Streams flowed not only along channels beneath the ice, but at the margin of the ice sheet, also in the re-entrant angles of the ice margin, and over the areas immediately in front of the ice sheet. Here, where the waters could spread over the flat lands, the violence of their rush was much diminished, and thick deposits of gravel and sand were formed. The irregular accumulation of these materials, accompanied by the irregular advance and recession of the ice front, produced a very irregular land surface, including hills, knobs, ridges, long hollows, and irregular depressions, known as kame moraines. The term kame is most appropriate for the knob, hill, or ridge built up by running water resulting from melting glacial ice, but it may be used also for those accumulations of stratified sand and gravel in which the topography is scarcely pronounced enough to result in well defined hills and hollows.

North of the O'Neil road, the kame territory extends at different points from more than half a mile to nearly a mile west from the Cincinnati pike. In the Hills and Dales area it includes all of the country east of the Wayne's Pass road, as far south as the Locust farm, and the Stroop road. South of Delco Dell and the Grand View farm, the kame area extends as far as Hole's creek. The gravel ridges are merely the most striking topographical features of the kame area.

48. The Outwash Plains in Front of the Glacial Ice Sheet

Kames, in general, are hill-like accumulations of sand and gravel near the margins of the ice sheet. Where glacial streams, at the margin of the ice, entered large, flat valleys, with only a moderate slope, their rate of flow must have diminished rapidly, resulting in large accumulations of gravel and sand, raising the level of the stream channel and causing overflows, resulting in a continual change in the paths of the stream channels. At a greater distance from the ice front, these streams must have carried chiefly sand and mud, forming immense sand plains and mud flats, such as the large flat lands extending from Dayton down the Miami valley as far as West Carrollton and Miamisburg. The large flat country west of the bluffs, and extending east of the Cincinnati pike as far as the western edge of the hill country on the Moraine farm, is a large outwash plain. Opposite the Moraine farm it has a width of fully two miles. The Huffman prairie area, extending from the Wright Aviation field, several miles northeast of Dayton, toward Fairfield and Osborne, is another outwash plain of large dimensions.



VIEW from the ridge southeast of the Emrick farm buildings across the flat lands of the Miami valley. The farmhouses are located west of one of the conspicuous gaps across the northern extension of the Walden ridge. The gap in the immediate foreground, occupied by the buildings, is through the Emrick ridge, one of the frequently interrupted ridges

Second hollow west of southern end of Cornfield hollow, in the kame area west of the Lohman ridge, south of Calvary cemetery. In this case the depth of the hollow is indicated by the curvature of the fence.

CHAPTER VII

PERIODS OF ADVANCE AND RECESSION OF THE GLACIAL ICE FRONT

49. More Than One Advance of the Glacial Ice Sheet

Even the Alpine glaciers vary in length. They move farther down the valley in winter and melt back in summer. A succession of warm summers, with comparatively little snow fall, may cause the ice front to melt back farther. Later, it may advance again. Considerable advances have been noted recently in case of some of the Alaskan glaciers, caused apparently by the shaking down of unusual quantities of snow from the upper mountain slopes, as the result of several earthquake shocks. The advance of the ice front lagged several years behind that of the great snow slides which accompanied the earthquake. Variations in the position of the ice front due to climatic changes, however, are likely to prove of longer duration.

During the melting back of the ice front, the various deposits at its margin form the terminal moraine, beyond which extends the outwash plain formed by the numerous streams escaping from the ice. Later, when the ice front readvanced, the debris-laden base of the ice sheet might be pushed on top of the earlier sand and gravel deposits, so as to leave a layer of till on evidently stream deposited materials.

In describing the glacial deposits exposed at the quarries at Beavertown, Leverett states that the main mass of till, 5 to 10 feet thick, overlies poorly assorted gravel and sand, horizontally bedded, while the latter often rests on a thin layer of till, in contact with the rock. Here the lower till evidently represents a remnant of an earlier ground moraine, covered with gravels and sand by streams issuing from the retreating glacier. The upper till represents a later ground moraine, which toward the margin of the readvancing glacier rode over the sands and gravels deposited during its period of retreat.

Till resting on considerable thicknesses of gravel may be seen also in the southeastern part of Dayton, along the northern edge of the hill land forming Ohmer Park. It is exposed at the numerous gravel pits at present to be seen south of the baseball park in east Dayton. Here the till frequently is 1 to 4 feet thick. It evidently rises from the low lands, on the north, toward the south, and indicates that the ice front was pushed up and over the water-laid deposits of sand and gravel, sufficiently to leave upon them the till, embedded within its lower parts.

Some of these changes in the ice front probably were of very minor character. At the great gravel pit northeast of the Calvary cemetery, a thin layer of till, only about 2 feet thick, projects southward into the gravels, being both underlaid and overlaid by gravel and sand. Similar thin layers of till occur in the gravel pit north of the reservoir along the Stroop road, on the Moraine farm.

When these deposits of till and gravel are of very local character it easily is possible that the same part of the ice front could furnish gravel and sand from the subglacial streams and till from the melting base of the ice sheet.

50. *Periods of Glacial Advance and Recession*

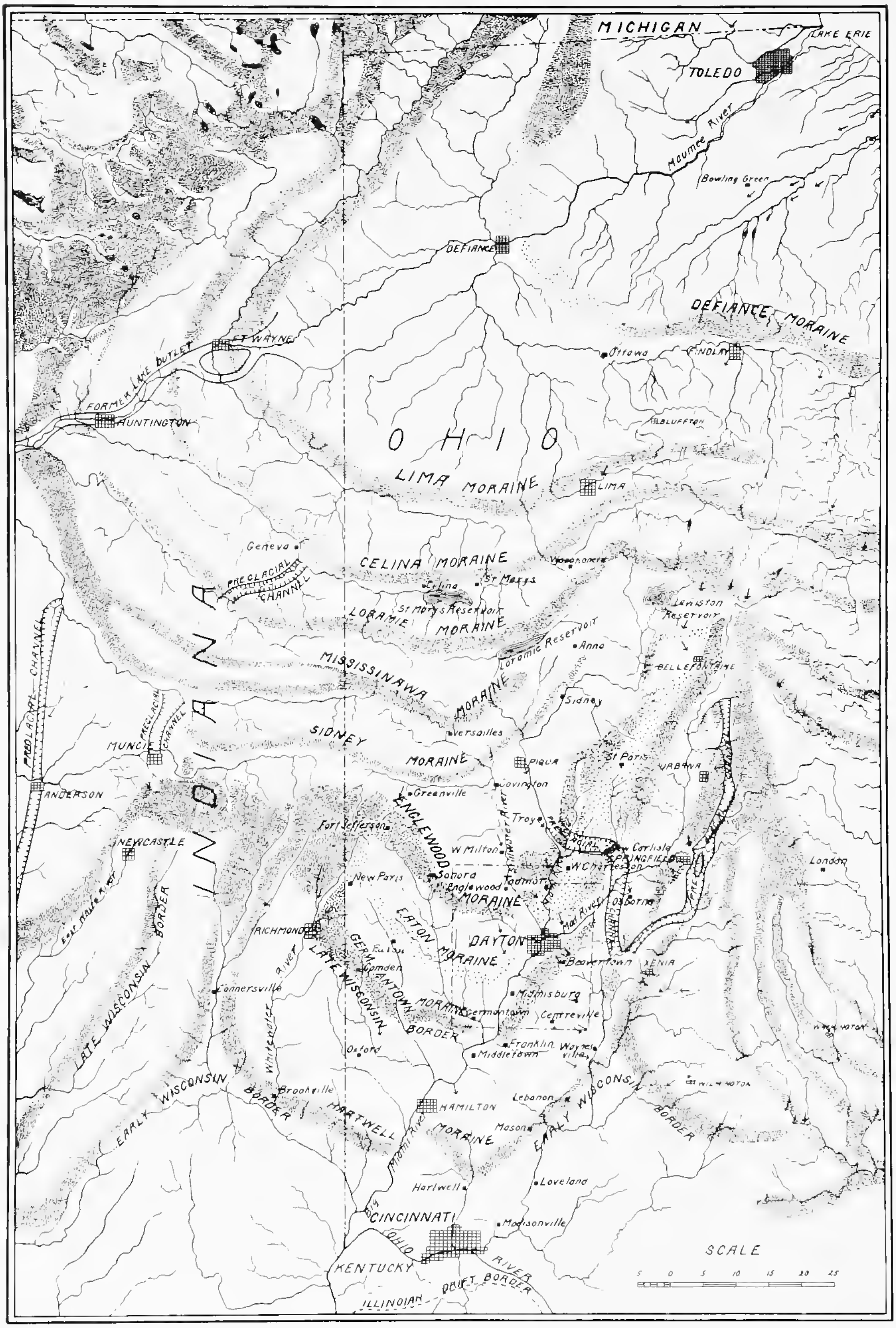
Some of the recessions and advances of the ice sheet involved the shifting of the ice front for such long distances, and involved such long periods of time, that it has been found convenient to give them names. The periods of advance of the ice sheet are known as those of invasion. Those of the melting back of the ice front have been called the interglacial intervals, because during the latter the ice disappeared over a large part of the marginal portions of the ice-covered territory. During the interglacial intervals both plants and animals pervaded the ice-freed country. The top layers of the glacial deposits were converted gradually into soil. The surface rocks began to show the influences of exposure to the weather. Their color changed to brownish and the included minerals began to decay.

Plant and animal life invaded the country. In the swampy areas, peat was formed. In the ponds, the accumulations of millions of shells, often very minute, gave rise to marl. In these various ways the interglacial intervals left records of their former existence.

The collecting of the evidence of the more prominent advances and retreats of the ice front of the former great continental glacial ice sheet represents the monumental work of quite a number of the most able American geologists, among whom may be mentioned Chamberlin, Salisbury, Leverett, Calvin, Upham, and Taylor.

The following list includes the names of the chief periods of invasion and retreat of the ice front, the invasions resulting in the deposition of drift and the retreats being accompanied by the formation of soil. In this list the first deposit of drift is placed at the bottom of the list and the last deposit at the top.

10. The present period of complete disappearance of the continental ice sheet.
9. The Wisconsin drift, the fifth invasion.
8. The Peorian soil, the fourth interglacial interval.
7. The Iowan drift, the fourth invasion.
6. The Sangamon soil, the third interglacial interval.
5. The Illinoian drift, the third invasion.



Map showing different positions of the ice front during the retreat of the Wisconsin ice sheet. Redrawn from Leverett's Monograph on the "Glacial Formations and Drainage Features of the Erie and Ohio Basins."

4. The Yarmouth soil, the second interglacial interval.
3. The Kansan drift, the second invasion.
2. The Aftonian soil, the first known interglacial interval.
1. The Pre-Kansan drift, the earliest known invasion.

The names for these deposits and periods are chosen from those areas in which the drifts and soils are typically exposed. The names Wisconsin, Iowan, Illinoian, Kansan, and Pre-Kansan are self-explanatory. The town Peoria and the river Sangamon are in Illinois. Yarmouth and Afton are towns in Iowa.

51. The Earlier Glacial Invasions of Ohio

No traces of the Pre-Kansan or Kansan invasions have been identified in southwestern Ohio. Both are chiefly of western distribution, although certain deposits in the northwestern part of Pennsylvania are regarded by Leverett as contemporaneous with the Kansan deposits.

The third, or Illinoian invasion not only reached the Ohio river, but crossed over into the limits of Kentucky in the area south of Cincinnati. In western Ohio, the terminal moraine marking its southern boundary, passed from Chillicothe southwestward to Ripley, on the Ohio river, and then along the river almost as far westward as Cincinnati. Before reaching that city, however, it entered Kentucky and took a southwesterly course as far as the bend of the Ohio river east of Warsaw. Westward, it followed the southern side of the Ohio river to the vicinity of Marble Hill, a small village south of Madison, in Indiana, beyond which the boundary entered the state of Indiana.

The Iowan invasion also appears to have been chiefly of western distribution, and its identification within the limits of Ohio may be said to remain uncertain.

52. The Terminal Moraine of the Earlier Part of the Wisconsin Invasion, in Ohio

The earlier part of the Wisconsin invasion of the continental ice sheet took place in the form of a series of broad lobes, 60 to 80 miles wide, occupying the larger drainage basins. Of these, the Miami lobe, at its period of greatest advance, formed an ice front reaching from Xenia to Waynesville, Lebanon and Mason. It extended almost as far south as Hartwell, 5 or 6 miles north of Cincinnati. North of Hartwell the front of this lobe turned northwestward, toward Hamilton; then southwest for a short distance, and again northwest, as far as Brookville, in Indiana, finally turning northward toward Connersville. This is the Hartwell moraine.

53. *The Germantown, Eaton, and Englewood Divisions of the Dayton Moraine*

The most southern division of the Dayton moraine extended beyond Germantown. This marks a later stage of the Miami lobe. This Germantown moraine may be traced from east of Harshmanville, across Huffman hill, to the bluffs, south of Dayton, and thence east of the Miami valley, by way of Carrmonte, the Moraine farm, and Delco Dell, to the hills east of Miamisburg and Franklin. From Franklin this moraine may be traced westward, south of Germantown, to Camden, and thence to Richmond, in Indiana.

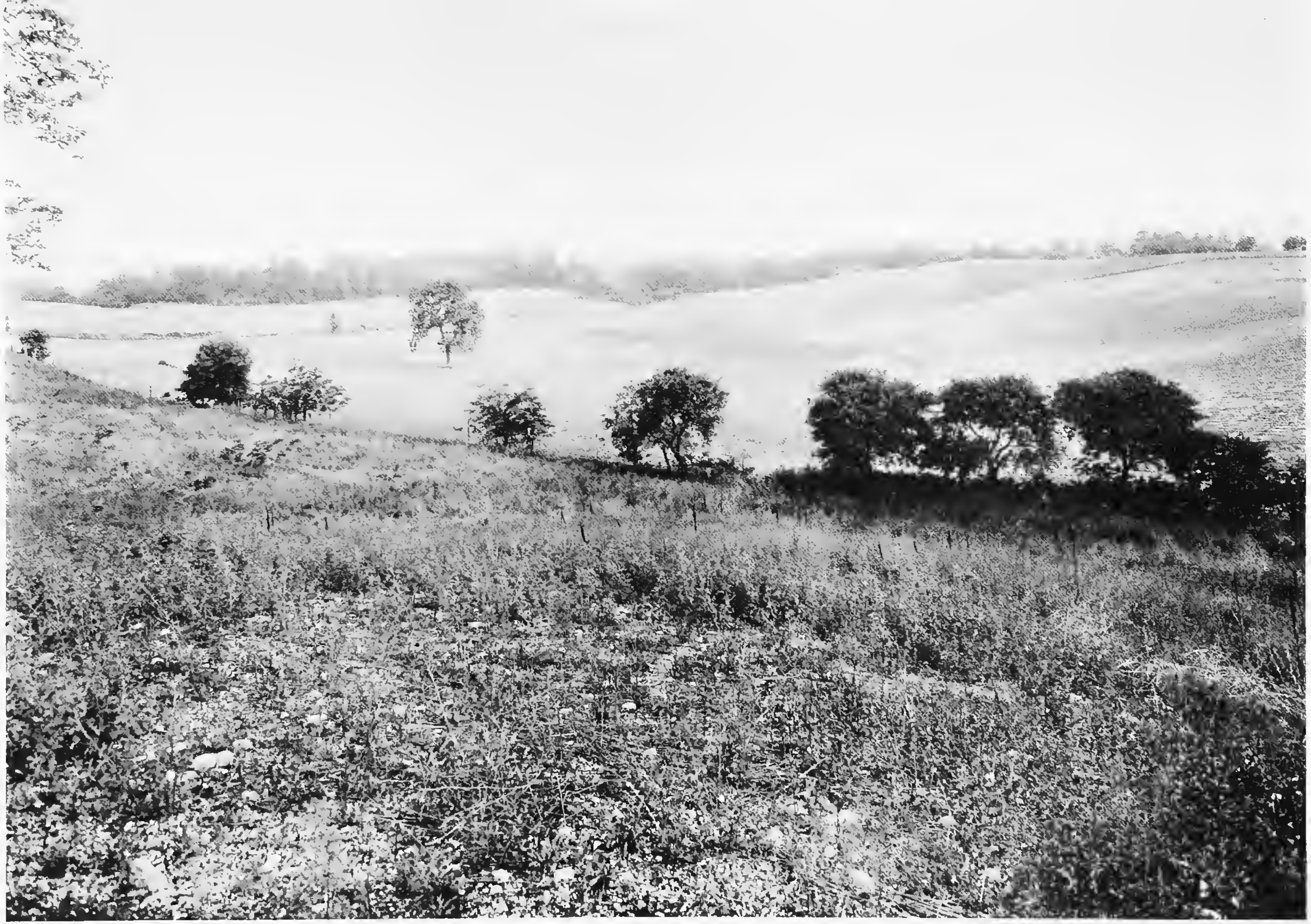
It is to this most southern extension of the late Wisconsin ice sheet, giving rise to the Germantown moraine, that the gravel ridges south of Dayton owe their origin. This Germantown division of the Dayton moraine usually rises about 20 or 30 feet above the level of the land on its southern side, although locally this elevation may rise to 50 feet. Roads entering this morainal territory from the south often rise abruptly on reaching the moraine. The width of the moraine, from north to south, is about two miles.

The middle or Eaton division of the Dayton moraine extends from Dayton View southwestward to a point three miles north of Germantown, and then curves northwestward to Farmersville, Ingomar, West Alexandria, and Eaton, passing east of New Paris, and west of New Madison. This middle or Eaton division of the Dayton moraine may be recognized readily by the very large number of boulders found on its surface. In a field near West Alexandria, Professor Orton actually counted more than 1,200 boulders, exceeding 2 feet in diameter, per acre. The majority of the larger boulders have a volume of 10 to 20 cubic feet, but some attain a volume of 100 cubic feet, or more. Most of these boulders consist of Canadian granites, green-stones, schists, and quartzites. But very few limestones or boulders of local origin, in Ohio, are present. The vast majority are subangular, or only partially rounded. Scarcely one in a hundred shows glacial scratching. Evidently, many of these boulders were carried along chiefly within the body of the ice, rather than shoved along at its bottom. North of Dayton, this boulder belt may be traced from Dayton View to the northern part of Riverdale, thence along the eastern side of the Miami, to West Charlestown, Christiansburg, and St. Paris. Its usual width, where it can be distinguished from the two other divisions of the Dayton moraine, is two miles or somewhat less. The southern border of this Eaton division of the moraine usually has a more gradual rise above the lands immediately southward than is true of the southern border of the Camden division of the moraine.

The northern or Englewood division of the Dayton moraine extends from the area east of Troy southwestward, crossing the Stillwater valley at Englewood, thence passing to Pyrmont, Sonora, Ithaca and Fort Jefferson. This division of the moraine also is covered with an abundance of boulders, but not in such great numbers or of such large size as in the case of the middle or Eaton division. The width of this division of the moraine, measuring across the moraine from north to south, varies from two to three miles.

These three divisions of the Dayton moraine represent three distinct stages in the retreat of the Wisconsin glacier. Each division records a period during which the glacial ice front remained comparatively stationary, shifting forward and backward within comparatively narrow limits. The spaces between consecutive divisions record periods during which the melting back of the ice front was too rapid to admit of the deposition of thick layers of till and other glacial deposits.

Northeast of Dayton the three divisions of the Dayton moraine approach each other sufficiently to more or less overlap. Hence, within this area, as far as Bellefontaine, it sometimes is impossible to distinguish the



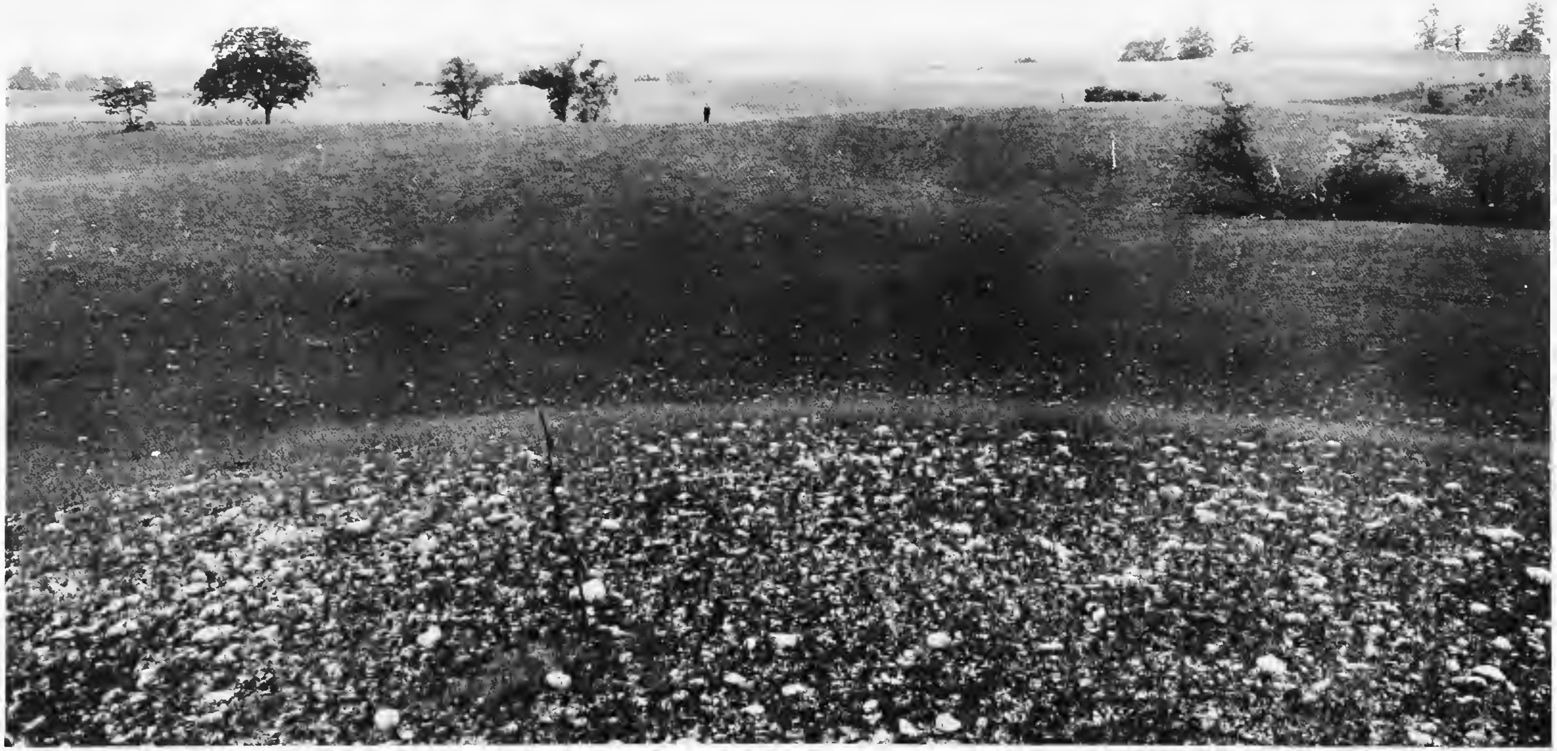
VIEW of the broad shallow valley between the Walden ridge (on the right) and the Schumacker ridge (seen only in the immediate foreground and thence toward the left.) The valley extends across this view from right to left. The abandoned barn on the Walden ridge is just beyond the right margin of this view component divisions from each other with sufficient accuracy to establish more than their general trend.

There were many such periods of comparative rest and of more rapid retreat during the decline of the Wisconsin glacier. At each period of rest a new terminal moraine was formed, ten, twenty, thirty, or some other number of miles back from the moraine formed at the preceding halt of the retreat. One of these later formed moraines extended almost as far south as Greenville. Another almost reached Versailles. Another reached the northern border of the Loramie reservoir. Another reached Celina and St. Marys. Another stopped north of Lima. Another reached a point north of Findlay. Still others terminated at points farther northward, but included within the boundaries of Canada.

54. Buried Soils

Each period of retreat of the glacial ice sheet exposed more and more of the ground to the activities of the sun. Under the influence of heat and cold, moisture and dryness, the ground began to weather. Owing to the presence of very small quantities of iron, it gradually assumed a brownish color. Seeds were blown in from southern territories, or were carried in by animals. The ground, barren at first, became clothed with vegetation. The roots, penetrating the soil, loosened the ground, and, by their decay, enriched it. Burrowing insects and worms brought up the finer particles of soil to the top and left the coarser particles behind. The final product was a surface layer of loosened earth, more or less intermingled with decayed vegetable material, which might be recognized by any one as soil.

Even when a soil formed during some interglacial period was buried under the deposits of some later readvance of the ice sheet, this buried material can be recognized as soil. In some cases it can be recognized as soil by the presence of the tortuous but very narrow cavities left by the roots. In other cases, the presence of burrowing insects assists in identifying it. Roots and parts of trunks of trees may be left in their original position. The brown color may be preserved. Of course, where the quantity of included vegetable material was so great as to color the soil black, the latter can be identified most readily.



VIEW at the head of the gully located east of the Emrick farm, looking from the high land along the line between VanBuren and Washington townships southwestward. The gully starts at the cluster of trees on the right. A man stands on the ridge in the middle distance. Farther back is seen the northward extension of the Walden ridge

Such buried soils occur at numerous localities in Ohio.

One of these ancient soils is exposed on the eastern bank of Twin creek, about a mile east of Germantown, immediately south of the locality where the traction road begins to descend the hill land rapidly, going westward. Here thick deposits of till line the western side of the creek, forming steep slopes. Only one or two feet above the level of the creek, darkened, almost black soil is exposed when the stream washes away the material which has slumped down from higher levels on the bank. In this soil Professor Orton recognized fragments of coniferous wood (probably cedar), cedar berries, grasses, sedges, and sphagnous mosses. To Professor G. F. Wright the deposit suggested a peat layer formed at the bottom of a kettle hole, a depression in part of a kettle moraine. Possibly this soil represents the interval between the deposition of the earlier and later Wisconsin advances of the glacial ice sheet.

At Wilmington, Ohio, Doctor Austin discovered in a similar peat layer the remains of beetles and other animal life indicating a general return to living conditions during the interval occupied by this period of peat formation. In fact, the border of life probably never was far south from the immediate front of the ice sheet. In the Alps, plants spring up almost in contact with the ice, as soon as the ground is exposed to the warming influences of the sun. Some of the heavy seeded trees, like those bearing the heavy nuts, such as hickory and walnuts, and including also the oaks, may have taken much longer periods of time to return to their original habitats, while trees with seeds that are carried by the wind, such as maples and poplars, certainly returned much faster.

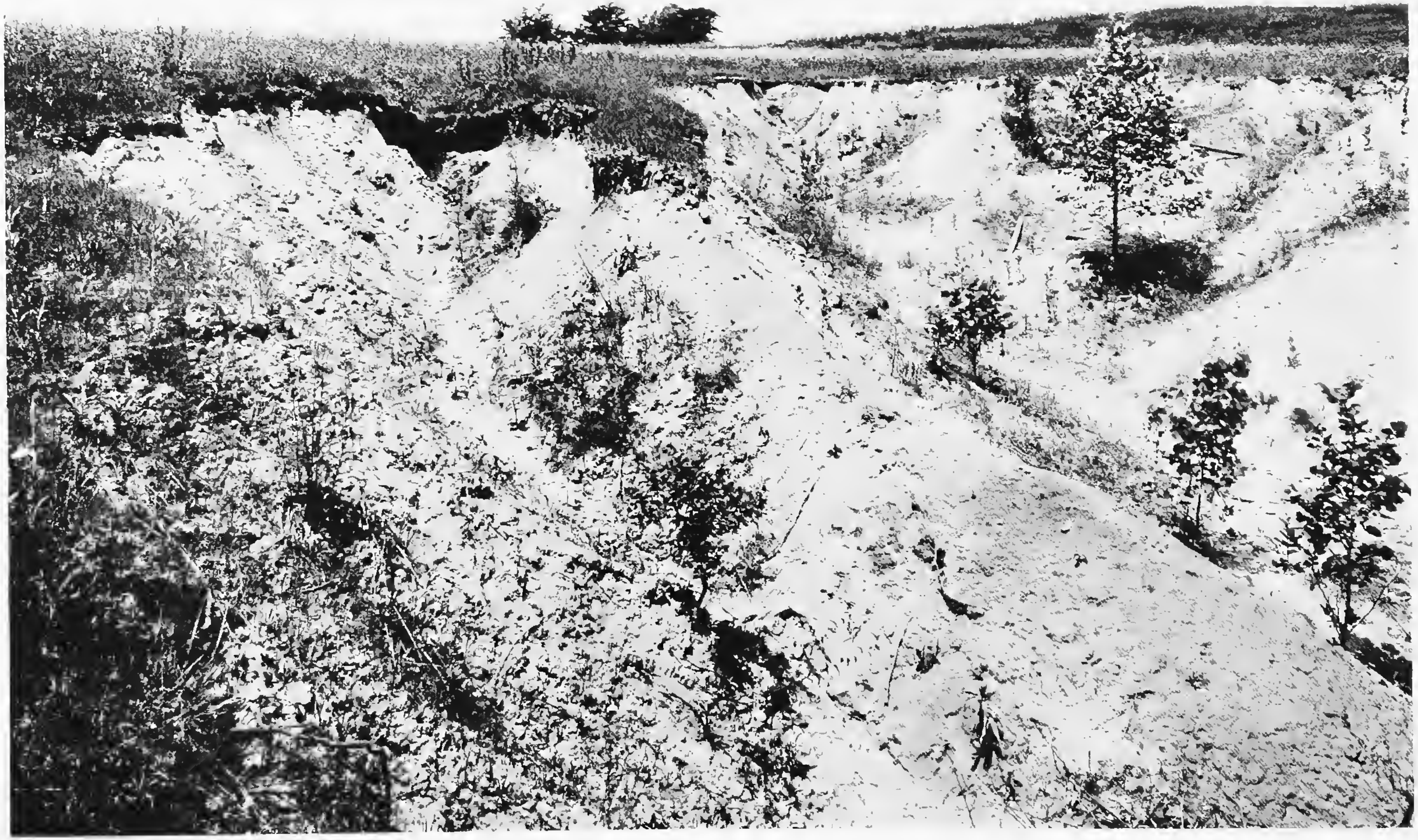
View from the ridge northeast of the Emrick farm buildings, northward, showing some of the spurs extending from the main ridge westward, immediately north of the gap. The gap is located in the rear of the strongly wooded land shown in this view.

CHAPTER VIII

DIFFERENCES IN AGE OF THE VARIOUS GLACIAL DEPOSITS

55. Difference in Degree of Weathering Shown by Deposits of Different Ages

Great differences in age probably exist between the deposits left by the earlier invasions of the ice sheet and those left by later advances. In Iowa, for instance, where all of the invasions mentioned have left deposits, the morainal material deposited by the Kansan advance of the ice sheet has weathered downward to depths varying from 12 to 30 and even 40 feet, while the Illinoian deposits have weathered only to depths of 3 or 4 feet, and the Iowan and Wisconsin deposits scarcely show any conspicuous signs of weathering at all.



VIEW of gullied lands at top of hill country northeast of Hole's creek bridge, looking westward from a point on the western side of the main gully. The gully lies southwest of the abandoned barn on the crest of the Walden ridge

By weathering is meant the change in color and the disintegration or decay of the minerals, resulting from exposure to air and water under the influences of considerable changes of heat and cold. The change in color usually is toward yellow or reddish brown. The feldspars in the granites change to kaolin and have a dull whitish instead of a more or less colored and glassy appearance. The hornblendes and biotite micas assume a more or less rusty appearance. Other changes take place, readily enough recognized by the mineralogist, but only crudely explainable to those who have given no previous attention to minerals.

In the older deposits, those of the Kansan invasion, the rocks have changed in color and have disintegrated, so that frequently it is necessary to break them open in order to secure sufficiently unaltered specimens to be able to identify them, while the rocks in the more recent deposits usually preserve their component minerals in a readily recognizable form, even at the surface.

Evidently the Kansan drift must be very much older than the Wisconsin. Recent studies by Frank Taylor would admit the elapse of even as much as 50,000 years since the retreat of the Wisconsin ice sheet began. Considering that this great elapse of time has been insufficient to produce any considerable change in the rocks deposited by the Wisconsin invasion, the deposits of the Illinoian advance must be much older.

But what shall we say of the age of the deposits made by the advance of the Kansan glacier? Weathering down to a depth of 8 feet requires more than twice the time necessary to produce weathering to a depth of 4 feet. Weathering proceeds much more slowly as the distance from the surface increases. Several hundred thousand years can not be too long a time to assign to the earliest deposits left by the continental glaciers.

56. Difference in the Degree of Surface Erosion Shown by Deposits of Different Ages

Differences in age between the deposits of the different advances of the continental glaciers are indicated also by the degree of change which has affected the general topography of the land surface left behind after each of these advances by the retreating ice sheet.

The Kansan morainal deposits, for instance, have been deeply carved by streams since the retreat of the ice sheet from these deposits. In some cases, river valleys more than 100 feet deep and over a mile wide have been cut into the Kansan deposits. Deep, open ravines, from which branch lateral ravines with gentle gradients, intersect the original morainal deposits in all directions, leaving intermediate areas characterized by rounded hills and ridges. It is the kind of topography known to students of physical geography as mature, with mature streams, valleys, and hills.

Contrast with this the changes to be noticed in the case of the Illinoian deposits. Here steep rain-cut gulches extend only for comparatively short distances, never exceeding several miles, back from the margin of the Illinoian morainal deposits and from the few large river courses. Three-fourths of the area covered by the Illinoian drift is not affected at all by stream action. It is an area of youthful topography.

Still more striking is the difference noticed on approaching the deposits left by the Iowan and Wisconsin advances. Here the glacial deposits usually still preserve their original contours. Very little cutting by stream action is in evidence. The topography is that of extreme youth, from the standpoint of a student of physical geography. No vital change has taken place since its original deposition.

57. The Gravel Ridge Territory South of Dayton Is Characterized by Very Youthful Topography

The territory between Calvary cemetery, Carrmonte, the Moraine farm, and Delco Dell belongs to the area of late Wisconsin deposits. Here also there is evidence only of the most youthful topography. The contours of the hills, ridges, hollows and valleys have suffered scarcely any change in form since they were left by the retreating ice sheet forty thousand or more years ago. There are no rain-cut gulches excepting where started recently by denuding the land of its forest covering. Very few streams have managed to establish themselves as yet, and these have not had sufficient time to carve channels of greater depth than several feet below the natural level of the ground. In fact, the youthfulness of the topography is the most striking feature of this area. But when youthfulness is measured in periods of forty thousand years, what is meant by old age, in geological studies, becomes more impressive.

58. Differences in Age Suggested Also by the Interglacial Deposits

The elapse of time represented by the different interglacial intervals is suggested by the different degrees of weathering shown by the immediately preceding and succeeding glacial deposits, and by the relative amount of change which has affected their surface topography.

The character of the deposits made during the interglacial periods themselves also may suggest different lapses of time. For instance, during the Aftonian interglacial interval, peat beds accumulated in some localities in Iowa to a thickness of 3 feet. The material consists chiefly of tamarack and moss. Many generations of plant growth must have been necessary to produce peat deposits of such thickness. Moreover, as may be seen in the following paragraph, there is evidence of abundant life during this Aftonian interglacial interval. But an abundance of animal life requires an abundance of vegetation, and it must have required many years for this vegetation to establish itself after the retreat of the Kansan ice sheet.

Forests were present also during the Yarmouth and Sangamon interglacial intervals. Their presence is detected chiefly in the peat deposits, but parts of tree trunks may be included in the immediately overlying till.

I have noted already the presence of fragments of wood in the peat deposit one mile west of Germantown, and in the till at the quarries northeast of Beavertown.

The greater thickness of the peat deposits during the Aftonian interglacial interval suggests not only the presence of considerable moisture during this period, but also a relatively greater lapse of time.

59. Differences in Age Suggested Also by the Character of the Animal Life Enclosed in the Interglacial Deposits

Possibly the most interesting evidence of the great age of the Aftonian deposits is given by the nature of the animal life then existent. In recent years, a considerable number of animal remains have been discovered in the Aftonian gravels, in Iowa. These include two or three species of elephant, one or two species of mastodon, one species of camel, two species of horses, and various other less familiar animals, some of large size and belonging to such genera as Megalonyx and Myolodon, names which have no meaning except to students of ancient fossil life.

All of these four-footed animals living during the Aftonian interglacial interval have one characteristic in common. All of the elephants, camels, horses, deer, and other animals then living, even when given familiar names, are different from the elephants, camels, horses, deer and other animals now living. They belong to entirely different species. This itself is an evidence of the great age of the Aftonian deposits.

Some of the Aftonian animals have been replaced by other species more or less closely related to the forms then living. Others have left no descendants, or close relatives, and have become entirely extinct.

On the other hand, during the Yarmouth interglacial interval some of the species of animals which still are in existence made their appearance. These include the wood rabbit and the common skunk. Associated with these more modern animals there still remained, during the Yarmouth interval, many of the more ancient types, which since have become extinct.

In fact, many of the animals now extinct must have persisted until quite recent times, geologically speaking, since their remains occur in swamps resting on the top of the late Wisconsin morainal deposits. Their age is at least more recent than these deposits. To this group of animals, now extinct, but persisting at least until the close of the late Wisconsin advance, belong the elephant and mastodon, and other less familiar animals, such as the megalonyx, tapir, peccary, musk-ox, and giant beaver.

60. The Methods of Identifying Fossil Animals

When we say that we have found the remains of some animal that lived many thousand years ago we mean merely that we have found the bones or part of the bones belonging to the skeleton. The other parts almost invariably decay.

In the frozen soils of northern Siberia, the bodies of the large elephant known as the hairy mammoth have been found with the flesh so well preserved that it was eaten by dogs. The most instructive specimen was found on the banks of the Beresowka river, in eastern Siberia. Its remains were taken to St. Petersburg. It appears that this animal, while quietly grazing, fell into a hole in the treacherous soil, and was injured so badly that it died within a short time. The body was soon frozen, and was covered by ice and soil so as to remain in practical cold storage for thousands of years. So well was it preserved that even its internal organs could be dissected and studied. The whole body was covered with yellowish brown hair, that on the breast and sides of the neck being long. The finer hair or wool, from 2 to 4 inches in length, formed a dense coat over the entire body, and among this wool grew the coarser and much longer hair, some of it attaining a length of 20 inches. The stomach was filled with the food the animal had just eaten and between the jaws was a mass of material which it had not had time to swallow before it died. Even the food in the stomach was preserved sufficiently well by the cold to permit the identification of many of the plants which the mammoth had eaten.

Various persons have claimed also to have found hair associated with the bones of another elephant known as the American mastodon. The hair decays much later than the flesh.

It has been asserted also that parts of the skin of prehistoric animals have been found associated with the skeletons where these had been mired in salt licks, or swampy places impregnated with salt, in which case the salt acted as a preservative.

As a rule, however, the remains of prehistoric animals occur only in the form of skeletons. If these skeletons always were complete, the identification of the animals frequently would be comparatively easy. As a rule, however, only parts of skeletons, and sometimes even only isolated bones or teeth are preserved. In these cases the identification of the remains is much more difficult, and requires the skill of those specialists who call themselves osteologists. These men, almost always connected either with some college or with some museum, make such a study of each bone of each animal that they frequently can identify an animal by a single bone. In such cases the bone possesses some characteristic not possessed by any other animal. Even when the exact identity of the animal can not be established, the group to which it belongs often can be determined. For instance, the animal may be identified as belonging to the group of cats, or horses, or deer, without determining the exact animal, since the group of cats includes the lion, tiger, leopard, jaguar, and many other animals, in addition to the ordinary cat. The group of horses includes also the ass, and zebra. The group of deer includes also the moose and elk and other animals. In the case of each bone there is some point at which the nerves or blood-vessels enter, some ridge to which the muscles are attached, some smooth surface at the joint, always in the same place and of the same form in the same bone of the same type of animal. By means of these characteristics, when known, the animals are identified.

Frequently, however, it is not necessary to identify an animal from a single bone. In fact, all the more satisfactory identifications are based upon the presence of several bones, sometimes of almost all the bones of an animal. The fact to be emphasized is that in the hands of an expert much can be learned regarding the identity of an animal even from a single bone. The teeth frequently serve as excellent means of identification, for instance, in the case of elephants, horses, deer, and various other animals. Perhaps the most satisfactory single part of the skeleton is the skull. The skull, of course, is composed of many bones, but these are so firmly grown together and possess so many peculiarities in different animals that the finding of a single skull almost invariably is sufficient to identify the animal with precision.

61. Where Prehistoric Animals Are Found

When animals die on the fields or in the woods, all except the skeleton soon decays, but even the skeleton disappears within a comparatively short time. You may have noticed that you do not often come across the skeletons of animals in the woods although animals are continually dying, and only a few ever are buried. Only in very dry deserts do skeletons remain when exposed on the surface for many years.

When buried in the ground, especially in clayey soil, through which water can not readily circulate, skeletons are preserved much longer. When mired in bogs, so as to become covered with the mud, especially if the bogs are very peaty, skeletons may be preserved many years.

In general skeletons are preserved for thousands of years when embedded in clayey soil or mud, far from the changeable influences of the weather. There are comparatively few such places. They consist chiefly of swamps, bogs, lakes, and the estuaries or deltas of rivers. Here the animal after sinking to the bottom has a chance of being covered by the mud, or sand, and it is chiefly in places which once were muddy or sandy that the remains of prehistoric animals are found. The enormous prehistoric reptiles, of which you may have read, which are found in the western states, occur chiefly in the deltas or estuaries along the shores of prehistoric lakes, which long ago have disappeared.

62. The Length of Time Involved in the Advance and Retreat of the Ice Front During the Wisconsin Invasion

In a recent paper read before the Geological Society of America, Mr. Frank Taylor presented the following estimates of the time involved in the closing episode of the history of the continental ice sheet. If about 40,000 years be estimated as the time necessary for the advance of the continental ice sheet, during the Wisconsin invasion, to its most southern limits, followed by 40,000 years during which the ice front retreated until it exposed the entire area now covered by the Great Lakes, and if to this be added 10,000 years for the time that has elapsed since the ice sheet left the region of the Great Lakes, then a total of 90,000 years is necessary to account for the lapse of time from the beginning of the Wisconsin invasion to the present day. Of the period of retreat, about 8,000 years are assigned as the time necessary for the Miami lobe to have melted back from the vicinity of Cincinnati as far as Defiance, in northern Ohio. This was followed by a period of 17,000 years during which the ice melted as far back as Port Huron, in Michigan, and the earlier glacial lakes in the Erie basin were formed. Next came a period of 15,000 years, during which the ancient glacial lake Algonquin covered the present sites of Lakes Superior, Michigan, and Huron, finding its outlet for most of this time chiefly by way of Georgian bay and the Trent channel into the basin of the present Lake Ontario. Of the time which has elapsed since the melting back of the ice sheet sufficiently to permit the discharge of the lake waters into the St. Lawrence river, about 6,500 years belong to the history of the Nipissing lakes, including about the same territory as Lake Algonquin, but emptying by way of the northern end of Georgian bay and the Ottawa river channel instead of by way of the much more southern Trent channel, and Mohawk river. For more than 3,000 years the Great Lakes are supposed to have had their exits very much as at the present day.

This estimate of a total of 90,000 years for the lapse of time since the beginning of the early Wisconsin invasion may be matched by another presented by Professors Chamberlin and Salisbury, of Chicago University, who estimated the time which has elapsed since the climax of the late Wisconsin invasion as somewhere between 20,000 and 60,000 years, while the climax of the early Wisconsin was attained between 40,000 and 150,000 years. By the climax of these invasions is meant their greatest distance south. In the case of the early Wisconsin, this distance farthest south extended to Hartwell, a few miles north of Cincinnati. The greatest distance south in case of the late Wisconsin invasion was a short distance south of Germantown. It was at the climax of the late Wisconsin that the gravel ridges south of Dayton were formed. These estimates do not take into account the time used by the invasions to reach their most southern boundaries during their periods of advance, but only the time occupied during their retreat.

63. *The Duration of the Glacial Ice Age*

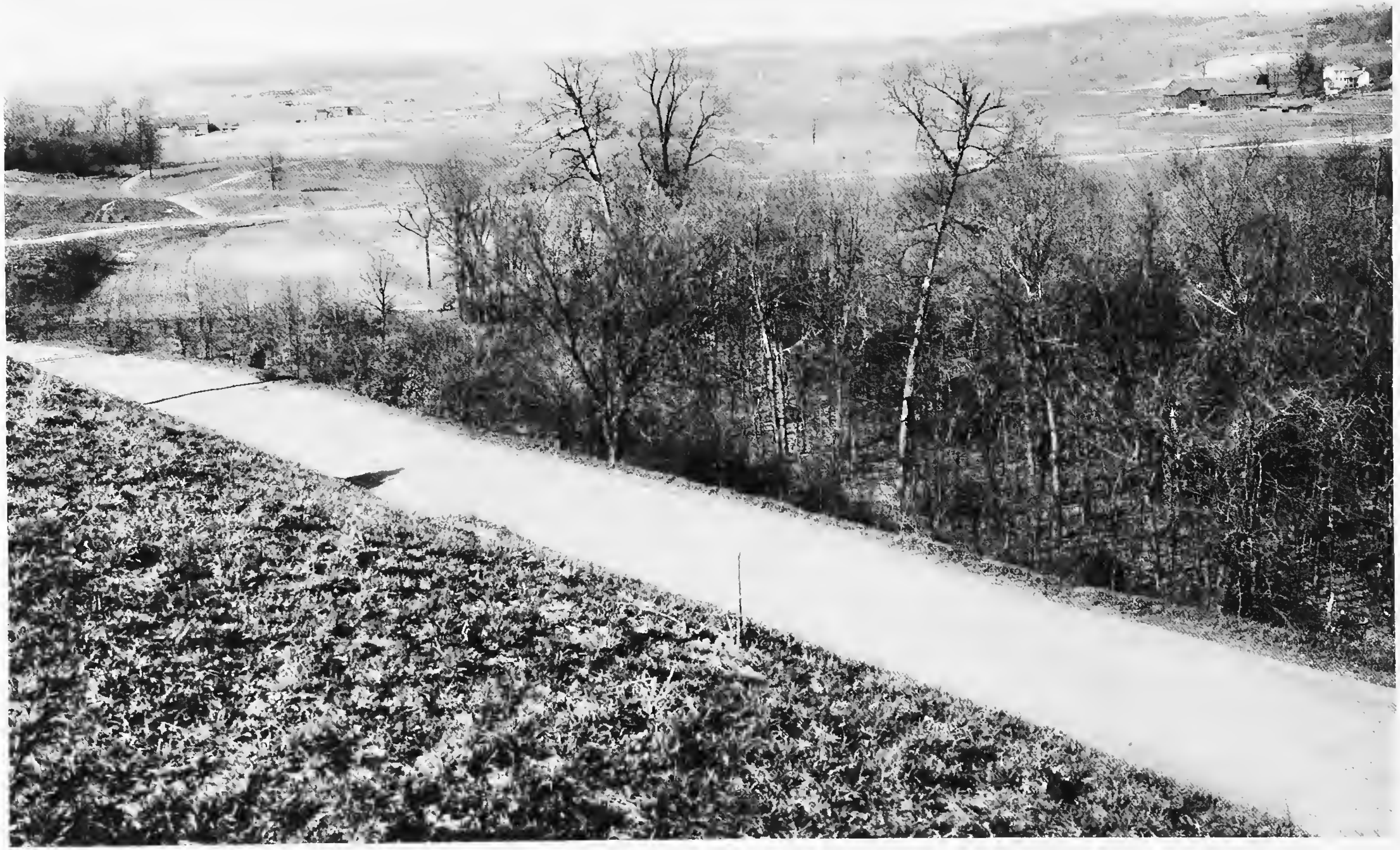
Chamberlin and Salisbury estimate the times elapsed since the various glacial invasions of earlier age than the Wisconsin as follows:

Since the climax of the Iowan.... 60,000 to 300,000 years
Since the climax of the Illinoian..140,000 to 540,000 years
Since the climax of the Kansan...300,000 to 1,020,000 years
Since the climax of the Pre-Kansan...A still greater number

Very little value is placed on these estimates by the professors cited beyond the fact that they give some sense of the proportion involved in the different time periods.

64. Distance of Retreat of the Ice Front During Interglacial Periods

In the case of the Alpine glacier examined by Tyndall, the rate of motion of the central part of the ice reached a maximum of 37 inches per day. Estimating the rate of motion of the continental ice sheet in crossing the comparatively level state of Ohio at one foot per day, it would require about 2,440 years to travel from the northern boundary of Ohio to the most southern point reached by the early Wisconsin invasion, near Hartwell, north of Cincinnati, and 2,200 years to reach Germantown, at the southern margin of the late Wisconsin invasion. These numbers, however, make no allowance for any melting back at the glacial ice front, which must have enormously retarded the rate at which the ice front advanced, since the latter depends not only upon the rate of motion of the ice, but also upon the rate at which the ice front is melted back. Evidently the advance of the ice front was much less on the average than 365 feet per year. If one-tenth of this rate of advance were considered ample, then 24,400 years would be required for the ice to advance across the state as far as Hartwell, and 22,000 years to reach Germantown. Neither estimate makes allowance for the time occupied by the retreat of the ice front during interglacial times. It seems scarcely likely that the continental glacier disappeared entirely from our continent between the Iowan and Wisconsin, or between the early and late Wisconsin invasions. In fact, it is improbable that during these intervals the ice front retreated even over an interval as great as that represented by the state of Ohio. Comparatively moderate retreats would be sufficient to account at least for what is known of these later interglacial periods.



VIEW from Eastview ridge, on the Moraine farm, across the Locust farm valley. The Locust farm buildings are on the extreme right and the National Cash Register Club buildings are seen on the left. This part of the valley is drained by the stream passing through the Ex-Governor Cox farm

View of the Great Mound southeast of Miamisburg, the tallest mound in the United States, serving both as a burial mound and as a signal mound. Photographed in 1888.

CHAPTER IX

THE EXISTENCE OF MAN DURING THE GLACIAL PERIOD

65. The Existence of Man in Europe During the Glacial Period

In Europe, the earlier fairly abundant evidences of the existence of man consist in the presence of rude chipped flint implements which occur in ancient river gravels. The implements consist chiefly of large, more or less flattened masses of flint, oval in outline, more or less pointed toward the top, and more or less angular along the sides. In length they frequently equalled 10 to 12 inches and show no evidence of ever having been attached to anything. They must have been wielded in the hand, and probably were used for every imaginable purpose for which a heavy cutting instrument might serve, from cutting down a tree, or digging in the ground, to killing an enemy. Other implements, such as scrapers, knifeflakes, or pointed instruments, were relatively rare. A moderately warm climate is suggested by the accompanying bones of two species of elephant, a rhinoceros, a cave-bear, a cave-hyena, and a hippopotamus. While none of these animals now live in Europe, it is probable that the three species last named have left descendants in the form of the brown bear of Europe, and the hyena and hippopotamus of Africa. The species of elephant and rhinoceros have left no descendants among living animals, the existing species belonging to different lines of descent. The climate appears to have been comparatively mild and the time appears to have been that of the second interglacial period. Man apparently lived chiefly in the open, in river valleys. Only implements occur; no parts of skeletons of human beings have been found in these gravels so far, unless a lower jaw found in the ancient sands near Heidelberg, in Germany, and part of a skull and lower jaw found in the gravels at Piltdown in Sussex, in England, be of the same age.

The lower jaw found near Heidelberg is remarkable for its massive appearance and the complete absence of a protruding chin; the teeth, however, are distinctly human and the canine teeth are no more prominent than the adjoining teeth. This jaw is sufficiently distinct from that of existing human beings to suggest its reference to a distinct species. The Heidelberg jaw was found associated with extinct species of elephant, rhinoceros, and cave-lion, and beneath beds containing blocks that had been transported by ice. Its age is regarded as somewhere in the earlier part of the Glacial period, suggesting that in Europe man may have made his appearance as early as the first interglacial period. In the Piltdown jaw, on the contrary, the canine teeth are much more prominent than in existing races of man, and the jaw presents other animalistic characteristics.

During the third advance of the glacial ice sheet in Europe, the two southern species of elephant, the southern rhinoceros and the hippopotamus disappeared. A type of elephant called the hairy mammoth, on the contrary, became common, and the woolly rhinoceros and musk-ox, two cold-loving animals, were added to the list. The hairy mammoth and woolly rhinoceros possessed thick coats of hair, adapted to cold climates. The descendants of the men who had made the implements found in the river gravels apparently were driven by increased cold and dampness to seek shelter under overhanging cliffs and within caves. Apparently the use of clothing, cooked food, and household management of a very primitive type began. The heavy, oval-shaped flint implements were displaced by large flakes with a sharper cutting edge. Flint scrapers, and lance points occur. The long bones of the horse, bison, and deer were used for implements.

More interesting, however, than the implements made by man, during this period of increasing cold, are the more or less well preserved skeletons, indicating his actual structure and size. So many of these skeletons have been found in the rock shelters and caves that man of this age may be said to be well known. The forehead was low and retreating. The eyebrow ridges were very prominent. The chin was undeveloped, sloping backward. Possibly this cave-inhabiting type of man was a descendant of the type found in the gravel southeast of Heidelberg, but he certainly was very distinct from the types of men now living. In fact, there is no reason for believing that living European races are descendants of these ancient cave dwellers. The origin of the living races is still a mystery, and may well have been some Asiatic source.

With the advent of the fourth advance of the glacial ice sheet, the reindeer, horse, cave-lion, and Irish elk make their appearance. The hairy mammoth, woolly rhinoceros, and cave-bear still flourished. Judging from his associates, the cave-lion must have been adapted to cold climates. The chief interest in this period of glacial advance, however, consists in the presence of skeletal remains of man evidently belonging to modern types. All of these possess a distinct chin. The most prevalent type, with narrow but high skulls, might have belonged to a modern European, but skeletons of the Eskimo type and those of negroid character also occur. These human remains occur chiefly in deposits representing the closing stages of the glacial ice age. During the retreat of the ice sheet, the climate became less cold and wet. The woolly rhinoceros disappeared. Reindeer and horses became common and were used for food. The more modern animals, still living, became numerous. Flints were retained chiefly for knives, spear heads, and slingstones. Bones were used for chisels, awls, pins, and spear tips. Later, bone needles came into use. Implements occasionally were carved or engraved, and sufficient of these remain to indicate the prevalence of considerable artistic instinct, of a primitive type. Later, drawings in black, red, and brown, with charcoal, red-ochre, and the oxide of manganese, made their appearance.

There is no evidence that man learned the use of the bow and arrow until after the close of the glacial epoch. In the course of time the Arctic animals disappeared from central Europe. Under the ameliorating conditions of climate man made enormous advances in civilization. The use of clay in the making of pottery was learned. Agriculture made its appearance. Modern man is the final result.

66. *The Existence of Man in America During Glacial Times*

Since the North American continent was connected with Asia by way of Alaska during the glacial ice age, the advent of man in America during this time was possible. As a matter of fact, however, no remains have been discovered in till or under undisturbed till deposits, unequivocally determining the existence of man in America during the ice age, nor have the remains of man been found associated with the bones of extinct animals, as in Europe. Hence it is probable that man made his appearance in America not earlier than the closing stages of the Ice age. In Ohio, Doctor Metz found a chipped pebble of some black rock of Canadian origin under 8 feet of loess, at Madisonville, 8 miles northeast of the center of Cincinnati, and a second chipped implement, 30 feet below the surface, on the western side of the Miami river, at Loveland, 10 miles northeast of Madisonville. To Frank Leverett, an experienced student of glacial phenomena, the evidence did not appear conclusive in either case, and the same may be said with reference to other supposed evidences of the existence of man on the American continent during the Ice age. This, however, does not prevent the possibility of such evidence appearing at any time with reference to other discoveries of prehistoric implements in America. It is desired here merely to bring out the fact that certain students of glacial phenomena are still skeptics regarding the value of the evidence presented so far.

66A. Climate During Glacial and Interglacial Times

It has been estimated that a lowering of the average annual temperature less than ten degrees would be sufficient to account for the former widespread glacial conditions. This brings up the question of climate.

This question has been attacked recently by Sinnott and Bailey from a peculiar angle, quoted with some modifications in the following lines.

It is well known that the percentage of woody plants in Europe, north of the Alps, is considerably less than in the corresponding parts of North America. In North America the vegetation could migrate easily southward at the advance of the ice and return northward at its retreat. In northern Europe, on the other hand, the southward escape of the vegetation was blocked, and it was crowded against the Alps, the Pyrenees, and the Mediterranean, thus suffering heavily by extinction. The extermination must have been more pronounced among woody plants than among herbs, since the latter are more able to withstand cold and otherwise adverse conditions owing to the presence of underground rootstocks and the abundant production of seed. The vegetation of northern Europe to-day seems, therefore, to be descended directly from that remnant which was able to survive in those parts of France, Germany, and England which the glaciers never reached. If the flora of northern Europe is indeed typically representative of that which flourished near the ice front during glacial times, the proportion of woody forms within it affords a valuable index as to climatic conditions during the height of the ice age. The facts seem to indicate that when the ice sheet had reached its greatest extent the country in its immediate front was neither a barren arctic tundra, as has sometimes been supposed, nor covered with a luxuriant temperate vegetation; but that the climate in general resembled that of the lower portions of the Alps or the Rockies to-day, being cold enough in winter to kill off all but the hardiest trees and shrubs, but not sufficiently cold to reduce the whole vegetation to the few perennial herbs and stunted shrubs which are characteristic of arctic regions to-day.

Of course, during the interglacial periods the climate presumably was warmer. Our knowledge of the life of the glaciated areas during the ice age is very largely confined to such life as existed during interglacial epochs, and here the existence of large animals, such as the elephant, mastodon, megalonyx, and various types of deer suggest considerable vegetation, and no extremes of cold even in winter. In fact, it is probable that during interglacial times the climate in areas as far south as Dayton may have been fully as warm as at present.

Gate on southern margin of large circle forming part of the Alexandersville geometric earthwork. This gate forms one of a number of such interruptions in the continuity of the earth wall forming the circle and is specially indicated on the accompanying map.

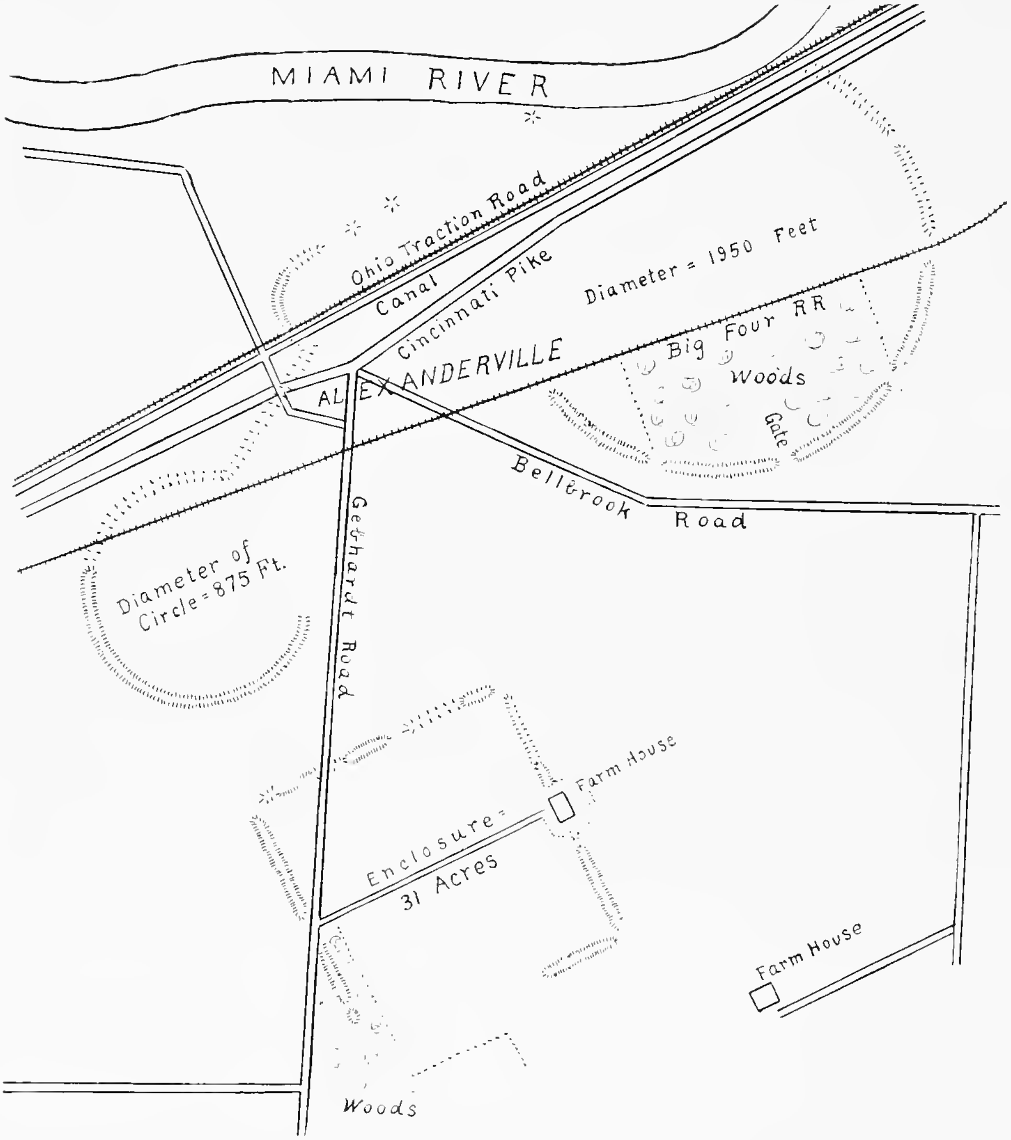
CHAPTER X

THE EARTHWORKS OF THE MOUND BUILDERS

67. The Geometrical Earthworks at Alexandersville

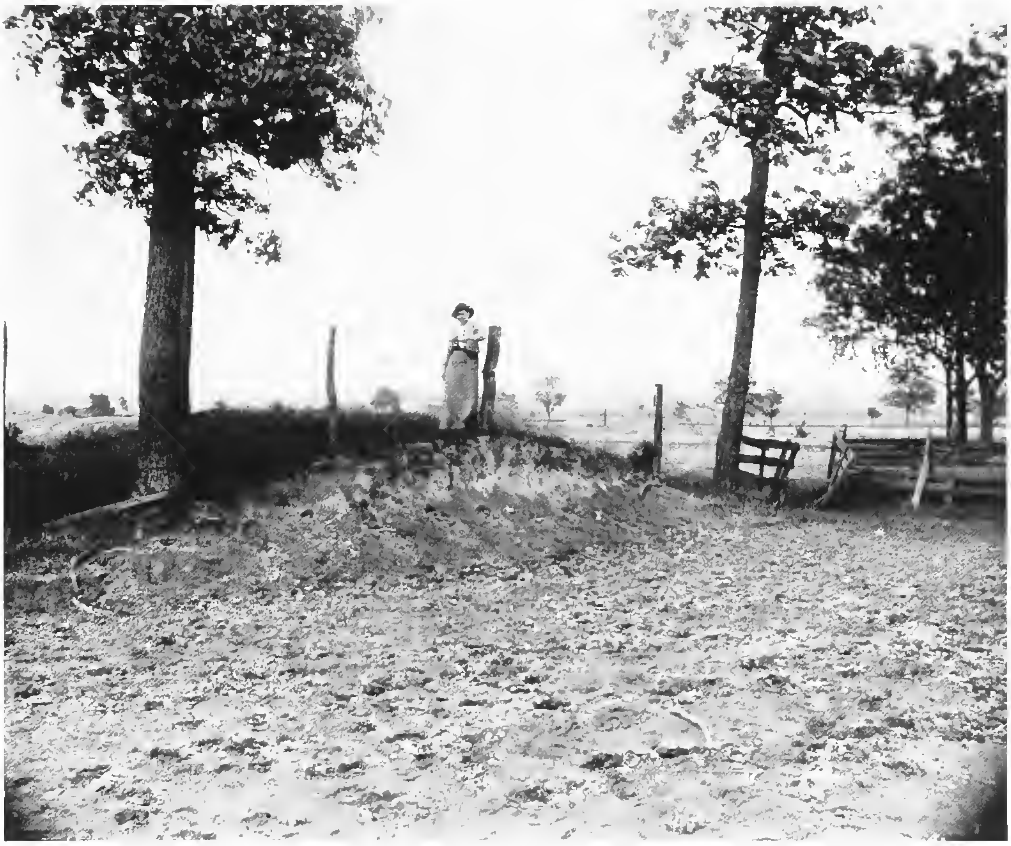
When the Europeans first explored that part of North America which extends from Ohio to Missouri and Wisconsin they found numerous evidences of the former presence of inhabitants who apparently had different habits and a different state of culture from the Indian tribes still in existence. Among the most common of these evidences were conical burial mounds, often containing implements unknown to living tribes. Hence these early inhabitants became known as mound builders. The long lapse of time since the existence of these mound builders was inferred from the fact that some of the trees found growing on these mounds were found to contain so many growth rings as to indicate an age of several hundred years.

In addition to the mound there were found also earthworks. Some of these consisted of earth-walls following the outlines of conspicuous hill tops, and evidently designed as forts. Such was the fort in the Calvary cemetery. In these forts there scarcely ever is any evidence of any attempt to



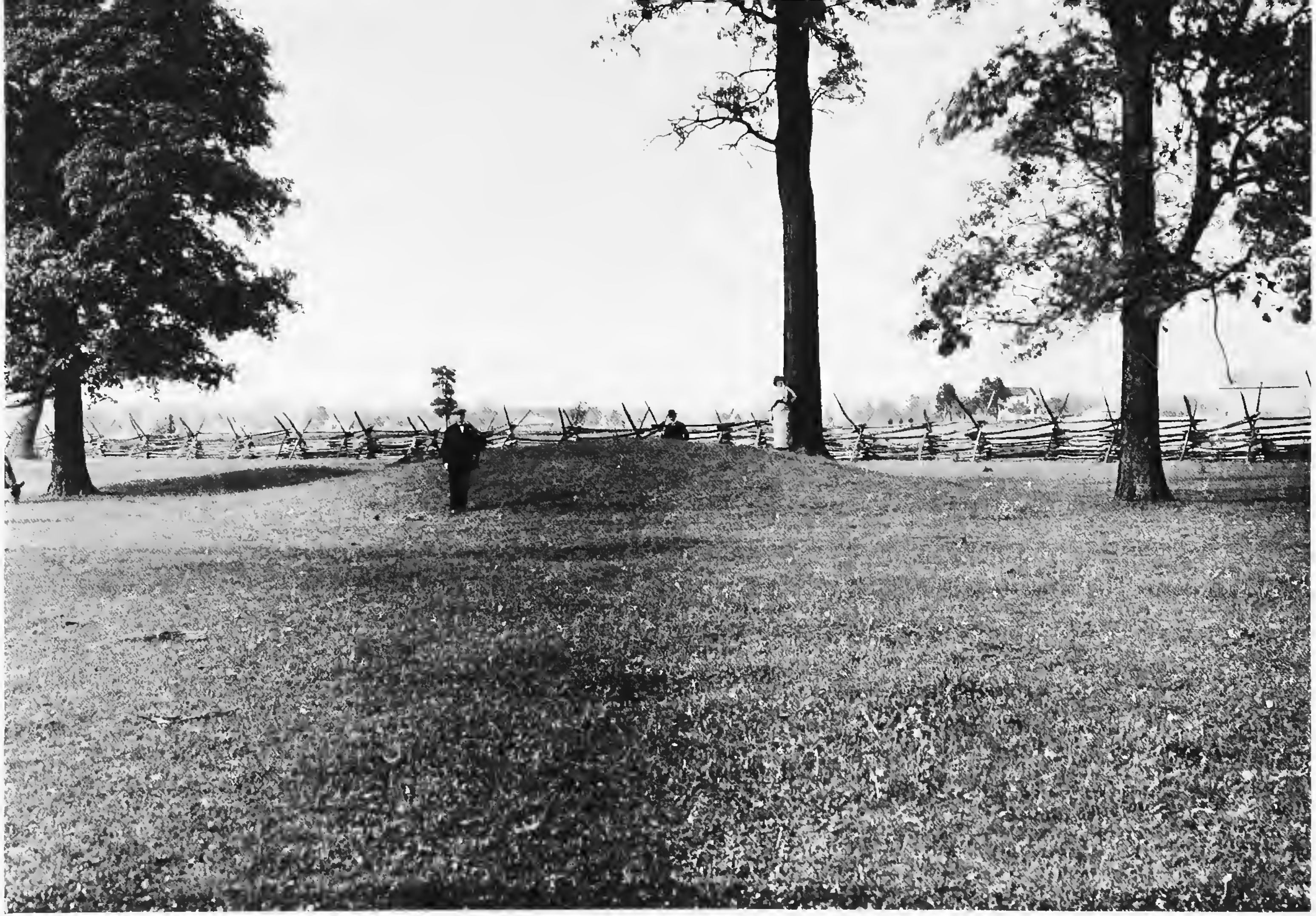
Map of geometric earthwork at Alexandersville, indicating the parts which still may be traced by closer set lines, and those which have disappeared by more distantly spaced lines. The breaks at equal intervals in the larger circle locate the "gates." Similar gates occurred at the corners and middle of each side of the square enclosure. The unfinished part of the square enclosure is at the southern end.

adapt the existing topography to the purposes in view beyond the addition of the earth-wall, and the occasional use of a ditch either immediately within the wall or at some distance back of the wall. The inhabitants knew the use of the bow and arrow, the spear, and the stone ax. We have no clear notion of their methods of warfare or of defense.



Cut across earth wall forming part of the large circle in the Alexandersville earthwork. This cut is located at the fence east of the gate which is specially marked on the accompanying map, and it serves to indicate the height of the wall.

In addition to these hill forts there occur in some areas earth-wall enclosures of a more advanced type. These consist usually of enclosures having the forms of squares or circles. Occasionally the walls of the squares are so bent at the middle as to produce a figure intermediate between a square and an octagon. In the drainage basin of the Scioto river these geometric



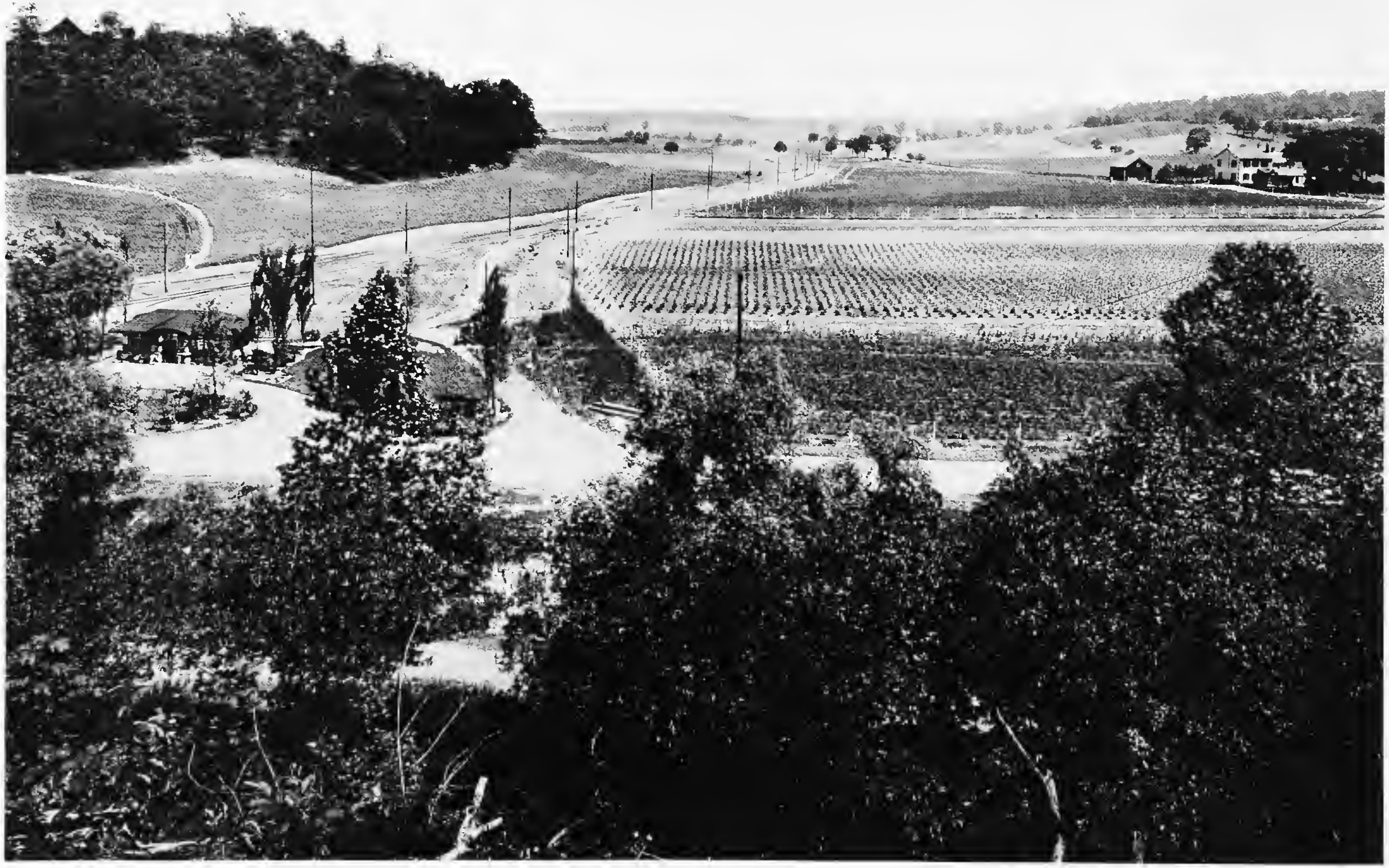
VIEW of mound of earth intended to form part of the southwestern wall (unfinished) of the square enclosure of the Alexandersville geometric earthwork. This mound is indicated on the accompanying map. The height of the wall is indicated by the man standing on the level ground directly behind it. As usual, there is no evidence of digging in the immediate neighborhood of the earthwork for the purpose of securing the soil used in building the wall earth-wall enclosures occur in groups consisting frequently of at least one square and two circles, the latter usually differing in size.

These geometrically constructed enclosures occur usually in the broad flat valley bottoms. In the Miami valley only two groups of this kind are known, and in neither case was the group of enclosures finished. Apparently the tribe building the enclosures in the Scioto drainage basin invaded the Miami valley, but were not able to maintain a foothold long enough to complete their earthworks. The tribes building the geometrically constructed enclosures may have been more or less contemporaneous with those building the hill forts, but apparently they were not identical.

One of the two groups of only partially completed enclosures occurs in Butler county. The other occurs in the vicinity of Alexandersville, a part being within the limits of the village. It lies within the flat lands forming the Miami valley between Dayton and Miamisburg. The distance from the Moraine farm and Delco Dell is two and a half miles southwestward.

Unfortunately the greater part of the earth-walls are in a poor condition of preservation. That part of the large circle which is preserved in the woods between the Big Four railroad track and the Bellbrook road, northeast of the center of the village, is in fairly good condition, the walls varying from 4 to 5 feet in height, and indicating the presence of several of the gates. The diameter of this circle was estimated at 1,950 feet. Formerly it reached the river bank on the north, but the western part never was completed. The square is located along the Gebhart road, which leads directly south from the center of Alexandersville. East of this road there is a farmhouse at the end of a long lane, and in the woods immediately south of the entrance to this lane is located as much as ever was built of the southern part of the western wall of the square. The northern parts of the same western wall may be traced less distinctly northward on the western side of the Gebhart road. The general direction of this wall is about 20 degrees west of north.

Only the eastern half of the southern wall ever was constructed, but even that part has been reduced by plowing to merely a low swell in the ground in the open field. The southern half of the east wall, south of the farmhouse, is distinctly defined, but the northern half of the east wall and



VIEW from the northern end of the Delco Dell grounds northward down the Locust farm valley, with the southern end of the Eastview ridge on the left, and the southern extension of the Highland area on the right.
The Adirondack ridge forms the hill outline in the extreme distance.

the eastern half of the north wall are very indistinct and only a low swell indicates the former course of the western half of the north wall. Open spaces or gates were present both at the angles and at the half-way points along the sides. The square occupied an area of 31 acres. The highest part of the wall was scarcely more than 4 feet in height.

The smaller circle was located directly northwest of the northwestern angle of the square. Its diameter was estimated at 875 feet. Only the southern part of this circle may be traced in the field between the Gebhart road and the Big Four railroad, south of the center of Alexandersville. It never was completed on its northeastern side and the southern end formerly extended across the railroad track westward and then curved northward in the field between the railroad and the Cincinnati pike, connecting with a short straight wall extending through the center of Alexandersville slightly east of north, where it connected with a curved wall, crossing the canal immediately north of the bridge at the Ohio Electric traction station, of which only a trace may be seen in the open field north of the station.

Years ago an old farmer by the name of Binckley owned a part of this property east of Alexandersville and attempted to leave it in an excellent state of preservation to posterity. He was the source of inspiration for many students of the so-called mound builders' relics, who came from Dayton and many more distant localities to see his collection. At present his collection is gone and the earth-walls are no longer regarded as sacred ground.

68. *The Irregular Earthwork at the Calvary Cemetery*

The irregular earthworks found on the tops of hills appear to have been made by a very different race of Indians than those who constructed the geometrical earthworks in the plains. In the vicinity of Dayton the old fort within the grounds of the Calvary cemetery was an excellent example of such an irregular earthwork. In the case of these forts there rarely is any evidence of any attempt to change the general topography of the land included within the fort. The earth-walls merely follow the existing sinuosities of the land surface. They usually skirt the margins of the hill tops and where crossing a gully plunge directly downward and ascend on the opposite side without any evidence of filling in any part of the land. If the earth-wall is accompanied by any ditching, the latter appears to have been comparatively shallow and always is located along the inner side of the wall instead of following the exterior. The ditch evidently was not expected to prove difficult of crossing to the enemy, but offered additional protection to the defending force.

In a preceding chapter the original outline of this fort is indicated. It is rapidly disappearing in the regrading operations of the cemetery authorities.

The mound at the northern end of the fort contained not only several skeletons of the mound builders, but also some of their trinkets. Some of the latter were exhibited for a long time at the Public Library museum.

69. The Miamisburg Mound

The tallest mound in the United States occurs on the hill tops about a mile southeast of Miamisburg. Its height is about 80 feet and its top is about 985 feet above sea level. While a burial mound, as is true of most other mounds, it apparently served also as an observation and signal mound. Apparently, most of these mounds were made by the tribes which constructed the forts on the hill tops. Not only do they occur most frequently near the top of high bluffs, but occasionally they are incorporated as part of the fort, as is the case, for instance, with the mound at the northern end of the Calvary cemetery fort.

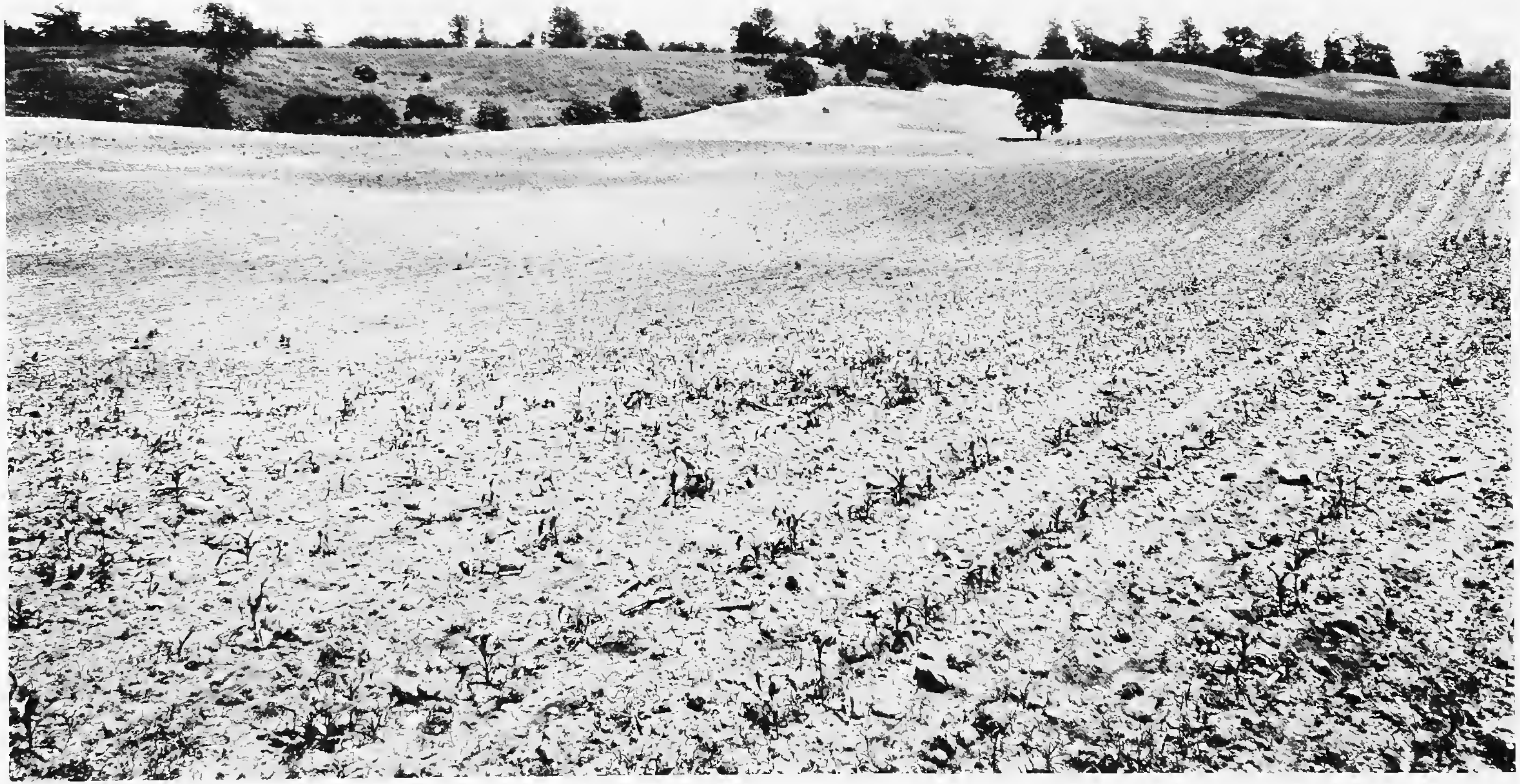
Natural bridge along road south of David church.

CHAPTER XI

GENERAL OBSERVATIONS ON THE GRAVEL AREAS SOUTH OF DAYTON

70. The View From Delco Dell Northward Along the Locust Farm Valley

The view from the Deeds cottage, at the northern end of the Delco Dell grounds, is one of the most charming in the area south of Dayton. Northward extends the flat Locust farm valley, with the western slopes of the Highlands on the east and the southern end of the Eastview ridge on the left. A glimpse of Ridgeleigh Terrace is seen rising above the trees on the crest of the ridge. The Henger homestead lies in the immediate foreground and the Locust farm is seen in mid-distance. On the eastern side of the valley lie the western slopes of the Highlands, consisting of a total thickness of more than 200 feet of sands and gravels, of which only the upper part rises above the valley level. The remainder of this sand and gravel



VIEW from the abandoned barn, at the top of the Walden ridge, northeast of the Hole's creek bridge, eastward, toward the Schumacker ridge. One of the minor depressions occupying the intermediate valley is seen in the foreground.

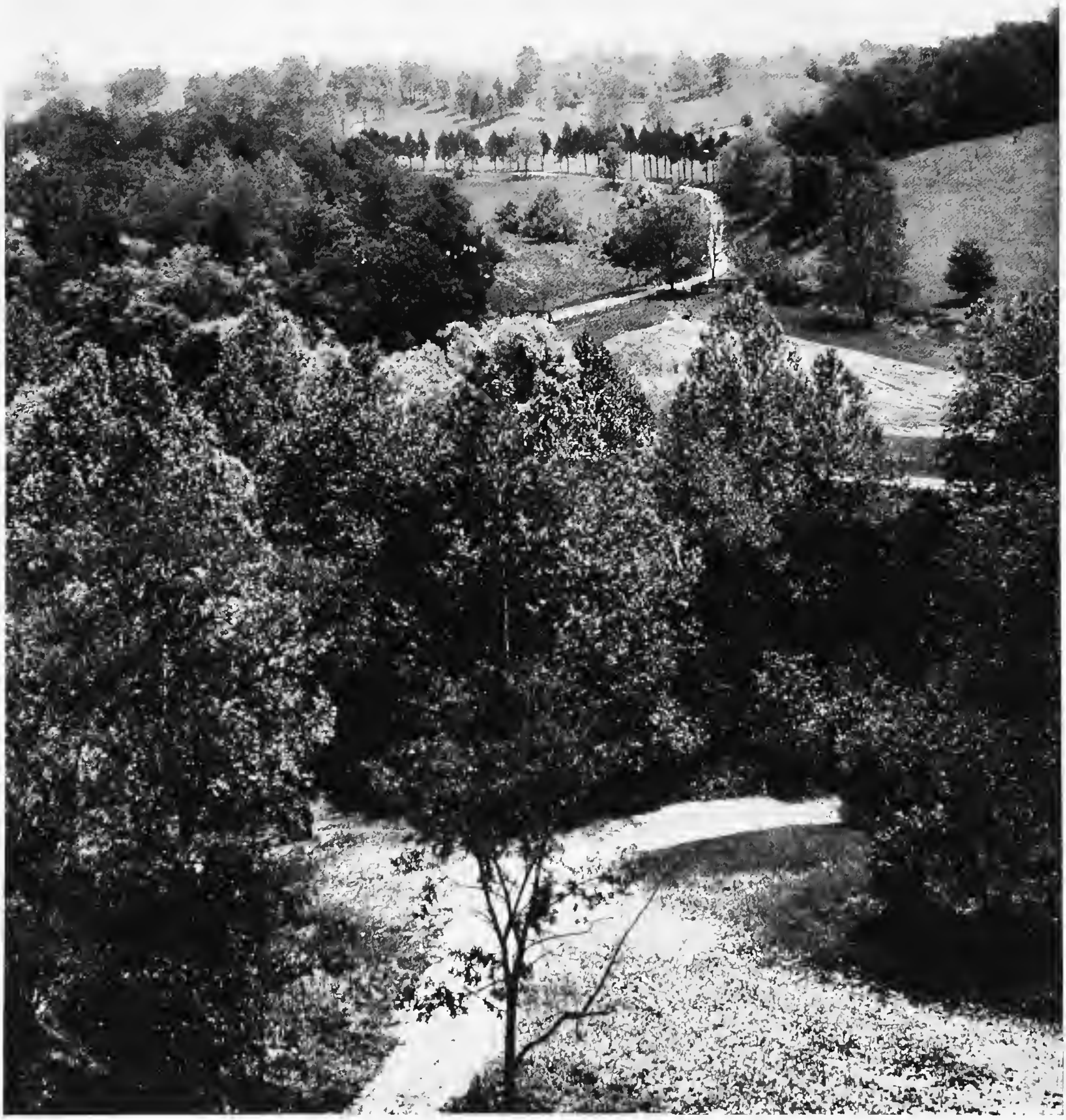
section can be detected only by boring wells, and the total amount of this deposit has not been determined with any degree of accuracy. All of this sand and gravel was deposited by running water, evidently by streams issuing from the melting continental glacial ice sheet, since, in the absence of ice, no streams of any appreciable size could have existed at such altitudes above the neighboring valley country.

Most of the surface of the ground in the Highland area is so irregular that it is not possible to detect the direction of any of the former stream courses. It is probable that the sand and gravel deposits were made by continually shifting streams at different stages of the retreat of the ice front. Many of the lobes of hill land project westward, from the Highland area toward the Locust farm valley, while the subglacial streams on the Moraine farm area, westward, and in the Hills and Dales area, northward, had a southeasterly course. The deposits in the Highlands probably were made immediately in front of the ice margin, rather than in stream channels beneath the ice.

The gravel pit on the hillside northeast of the Locust farmhouse shows the arrangement of the gravels in horizontal layers, due to their deposition by running water. Half a mile northeast of the farmhouse, at the southern margin of the Hills and Dales area, is seen the Hills and Dales Club house, northwest of which the crest of the Adirondack ridge may be traced as far as the woods at Round camp. Beyond this point the woods cover the western slopes of the ridge. This Adirondack ridge marks the channel of one of the streams flowing beneath the ice sheet during its final stage of melting away at the close of the glacial ice age. The buildings of the N. C. R. club can be recognized in the distance. Beyond this point, the Locust farm valley extends northwestward between the Adirondack and Cincinnati pike ridges, connecting with the Miami valley at Carrmonte.

71. *The Locust Farm and Kohl Branch Valleys*

For the greater part of its length, the Locust farm valley is remarkably flat. At the Delco Dell station its elevation is about 840 feet above sea level, and this is the elevation of its margin for most of the distance north-



View from the southern end of the Schumacker ridge southeastward across the Kohl branch of Hole's creek, toward the till-covered areas on the hillsides opposite.

ward as far as the hill land north of the N. C. R. club grounds. Even at the entrance to the lane leading to the Calvary cemetery, at the bend in the Cincinnati pike, the elevation, at the side of the valley, is still as high as 790 feet above sea level. South of the Stroop road, east of the Delco Dell grounds, the Locust farm valley rises within a short distance to an elevation of 980 feet and then becomes remarkably flat again as far as the southern end of the David road, where its altitude is 900 feet. The watershed farther southward, separating the Locust farm valley from that occupied by the Kohl branch of Holes creek, is less than 20 feet higher.

The Kohl branch valley is much more irregular than the Locust farm valley, but it is similar in being bounded on the east by an irregular hill-front, forming a southern extension of the highland area, while on the western side there is evidence of subglacial stream deposits in the form of a gravel ridge extending through the wooded area south of the Van Buren-Miami township line, along the western margin of the Schumacker farm. This Schumacker ridge is well defined only along the southwestern quarter of the farm. Northward, toward the township line, it merges into the more or less irregularly undulating hill land which characterizes the area along this part of the township line.

An eastward continuation of the southern end of the Schumacker ridge would connect it with the hill land along the northeastern part of the Rahn farm. South of this point there is no evidence of the former presence of subglacial streams. At least no well defined gravel ridges are known at present from this territory.

72. The Eastern and Western Boundaries of the Miami Valley in Pre-Glacial Times

In order to secure an approximate idea as to the general appearance of the country before the advent of the glacial ice sheet it is necessary to imagine what the country would look like if all glacial deposits were removed. This implies the removal of all till and kame deposits: in other words, of all clay, gravel, sand, and boulders brought in by the ice sheet or washed along by the streams flowing beneath the ice sheet or issuing from the ice front. This would leave only the original rock layers with such remnants of the covering soil as locally might remain from the days preceding the ice age. As a matter of fact, there is no evidence at hand that any of this former soil still remains in place anywhere beneath the subsequent deposits of glacial material. Moreover, only few exposures of the original rock of this section of the country, in the form of continuous layers of limestone, more or less interbedded with clay, are known within the area south of Dayton here under discussion, although, of course, these continuous layers of limestone must be present everywhere beneath the glacial deposits. The continuous layers of limestone merely are covered up by subsequent glacial deposits.

Limestone layers belonging to the upper part of the Richmond group, and full of fossils, formerly were exposed in road-side quarries where the Cincinnati pike leaves the southern end of Main street. Exposures occurred also at lower levels along the eastern end of the bluffs, almost as far west as the Jewish cemetery. Along the Gutwein property, on the Cincinnati pike, this Richmond rock rises to an elevation of 850 feet above sea level, and originally it occurred at still higher levels in the hills farther southward, in the adjacent parts of Oakwood.

Another exposure of the upper part of the Richmond group of limestones occurs in the southern part of Oakwood, along a northern branch of Meadow brook, where it is crossed by the Houk road, and thence for some distance up stream. Here the exposures, full of fossils, extend from 830 to 875 feet above sea level.

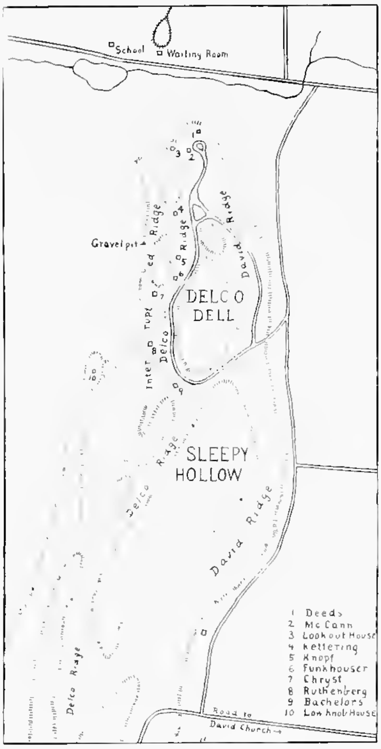
South of Oakwood no exposures of continuous limestone layers are known, for a distance of four and a half miles, until Hole's creek is reached. Here limestone occurs along the creek where it is crossed by the Mad River pike, about three miles southeast of Alexandersville. This locality is less than a mile south of the hill lands recently acquired by Mr. Deeds and added to ridge properties extending from Moraine farm and Delco Dell southward to Hole's creek. Here the middle parts of the Richmond group are exposed along Hole's creek, west of the Mad River pike, as far down as the 780-foot level above sea. Southward from the bridge, up a small branch, the exposures continue to the 820-foot level, and, no doubt, the rock rises to still higher levels beneath the glacial deposits still farther south.

Southwest of Hole's creek no exposures of bedded limestone are known until the area west of the Springboro pike is reached. Here limestone occurs along two ravines, the best exposures being found about three-fifths of a mile west of the Springboro pike, where a small stream flows northward toward the flat lands surrounding Alexandersville. From this point, as far south as Franklin, exposures are not infrequent along the hill front forming the eastern side of the Miami valley. A magnificent exposure occurs along the railroad track south of Miamisburg, where the Big Four railroad cuts through an angle of the hill. Here the arrangement of limestone in continuous layers, separated more or less by clay, is seen on a large scale. Fossils are common in some of the limestone layers, and some can be washed out in perfect condition from the intervening clay. The exposures belong to the lower and middle parts of the Richmond group.

As far as may be determined from the few exposures cited, the eastern margin of the pre-glacial valley at present occupied by the Miami river formerly extended as far east as a line drawn from the bluffs, east of the Jewish cemetery, southeast through Oakwood to the Lebanon pike. Between the O'Neil and Stroop roads this eastern boundary must have passed east of the pike since the well bored at the Doctor Scheibenzuber residence passed through 180 feet of glacial clay or till without reaching the underlying rock. From this point the eastern margin of the valley probably curved southwestward, more or less parallel to the Mad River pike, as far as Hole's creek, and then more westward to the hill front south of West Carrollton.

On the western side of the Miami valley, rock exposures are seen along the White line street car tracks east of the Soldiers' Home. From this point rock exposures are frequent along the hill front southwestward as far as a point a mile south of the Soldiers' Home, on the Carrollton pike. Exposures occur also along the Narrows, where the hill land borders the Miami river, about a mile and a half northwest of the Moraine station on the Ohio Electric railroad. The locality may be reached readily by the river road following the western bank of the Miami river southwest of

Dayton. Southwest of this point there are no exposures of rock until the hills west of Miamisburg are reached. It is through this gap between the narrows and Miamisburg that the Miami valley of pre-glacial times may have passed. At any rate, the narrow part of the valley south of Miamisburg, only a little over half a mile in width, scarcely appears an adequate exit for the wide pre-glacial valley extending from West Carrollton northward beyond Dayton and having a width for a considerable distance of more than two and a half miles.



Map of Delco Dell, suggesting the former presence of a continuous ridge west of the Delco ridge. This former ridge is now interrupted by gaps. The former continuation of the ridge across the gaps is indicated by dotted lines. Only those cottages and other buildings which were found useful in locating the various gaps and transverse ridges are indicated.

North of Oakwood, the eastern margin of the pre-glacial valley now occupied by the Miami river is indicated by several outcrops. In regrading the land south of Irving avenue and east of the Schantz park, limestones belonging to the Richmond group were exposed up to a level of 870 feet above sea level. About half a mile southeast of the asylum, east of the Beavertown pike, the Dayton limestone formerly was worked in several quarries between 940 and 950 feet above sea level. Similar quarries existed between half and three-quarters of a mile north of Belmont, and the underlying Richmond strata are exposed in the ravine northeast of Ohmer Park. Richmond limestones are exposed also along the Pennsylvania railroad, south of Huffman hill, and at the northern end of the Huffman hill area, where the traction line to Springfield crosses the railroad track.

73. The Delco Dell Ridges

The charm of the Delco Dell area consists chiefly in the numerous and extensive views across the open country toward the north and northwest. Broad, flat fields, bordered in the distance by steep hill fronts, characterize the landscape. Especially at evening, when the colors of the setting sun illuminate the sky, and the valley plains begin to darken, Delco Dell is a haven of rest. There are times in the day when the views across the eastern valley also are pleasing. To a geologist, however, the chief interest in the Delco Dell area consists in the presence of the steep narrow ridges and included hollows, to which reference has been made so frequently in the preceding pages.

The western or Delco ridge has been used for most of the cottages. Here its ridge character is seen best directly west of the hollow which lies west of the entrance to the Delco Dell grounds. It becomes still more conspicuous farther southward where it forms the western boundary of Sleepy hollow. The David ridge also is most conspicuous along the Sleepy hollow, of which it forms the eastern border. At the northern end of the Delco Dell grounds these ridges merge.

One of the most interesting hollows enclosed by any of the gravel ridges south of Dayton is the Sleepy hollow, at the southern end of the Delco Dell grounds. Considering its depth and width and the steepness of its walls, it is remarkably large. Its bottom is flat and has accumulated considerable soil, so that the northern half has been used for a long time as a cornfield. This brings up the question, where did the soil come from?

Sleepy hollow, in the Delco Dell grounds, looking northeastward across the plowed field in the bottom toward the David ridge, with part of the Delco ridge showing on the left.

In fact, where did any of the soil on or between the gravel ridges come from?

74. *The Origin of Soil*

This question of the origin of soil always is a matter of interest. Many factors enter into the formation of a soil and a few of these may be enumerated here in connection with the problem at hand.

In the areas south of those formerly covered by the ice sheet, soil consists chiefly of the finer material left behind by the decay of the country rock. In a limestone country, the soil consists of decayed limestone. In a sandstone country, the soil consists of decayed sandstone. In the process of decay some of the ingredients of the decaying rock may be removed more or less in solution, but, in general, the chemical character of a soil depends upon the chemical constituents of the rock from which it was derived. Soil is produced also by the action of streams. The grinding action of the rocks, pebbles, and sands against each other reduces a part of the material to a fine silt which may be left, at times of freshets, on the neighboring flood plains. In the case of silts, the chemical constituents consist of a mixture of all the materials resulting from the grinding up of all of the rocks represented along the stream channel.

In areas formerly covered by glaciers, soils usually consist chiefly of the material resulting from the grinding up of the rock by the moving ice, or of the sand and silt carried by the glacial streams. It is quite evident that the till or clay included within the lower part of the ice sheet must consist of a mixture of all the rock over which the ice sheet passed, or at least of all the rock with which it came into sufficiently forcible contact to exert a grinding action. Hence, glaciated countries usually present soils rich in all desirable mineral ingredients, and, provided the physical texture of these soils is satisfactory, such soils usually are very fertile. Their physical texture is likely to be best where the clay is more or less mixed with sand, as in the great outwash plains in front of the moraines.

75. The Accumulation of Soil

Frequently several inches of soil cover a gravel hill or plain like a thin mantle. In this case the soil may represent a later deposit than the gravel but frequently it consists merely of the finer particles of clay and sand, originally a part of the underlying gravel, but brought to the surface later by burrowing insects, grubs, earthworms, and other creatures. An ant hill is an excellent example of finer material brought up from below the surface of the soil, frequently from a depth of 6 to 8 inches or even more. The coarser material is left behind and gradually settles into the spaces left behind by the removal of the finer material which has been carried upward.

Most of the soil covering the gravel ridges south of Dayton probably was formed by the method last discussed; it represents the labors of myriads of burrowing animals of all kinds, bringing up the finer particles of clay and sand from among the gravel deposits beneath. Along the tops and sides of the gravel ridges, the clay ingredients often are moderate in

Nollman pond, looking north.

Nollman pond, looking south.

Note the absence of drainage in either direction. The pond occupies the bottom of one of the hollows between the Pike and Chapel ridges, and is located west of the Nollman house. Part of the water evaporates and part soaks into the gravels beneath. Only during rainy weather is the water supply sufficient to keep it comparatively fresh.

quantity, so that the covering soils here often are very loose and are readily washed away after the protective covering, consisting of the matted roots of grass and other plants, has been removed.

In the hollows between the gravel ridges the clay ingredients usually are greater. The finer ingredients probably are washed down the sides of the gravel ridges in sufficient quantities during rains to produce thicker soils here. In most of the hollows among the gravel ridges the soil does not contain sufficient clay to hold water readily, so that even after a heavy rain there are no ponds. In a few of the hollows, there is sufficient clay to permit the formation of ponds which usually, however, become dry during the summer. Only a few ponds are known within the gravel ridge area which last practically all year. Two of these ponds formerly existed in the area west of the Cincinnati pike, but at present they become very stagnant or dry up during summer.

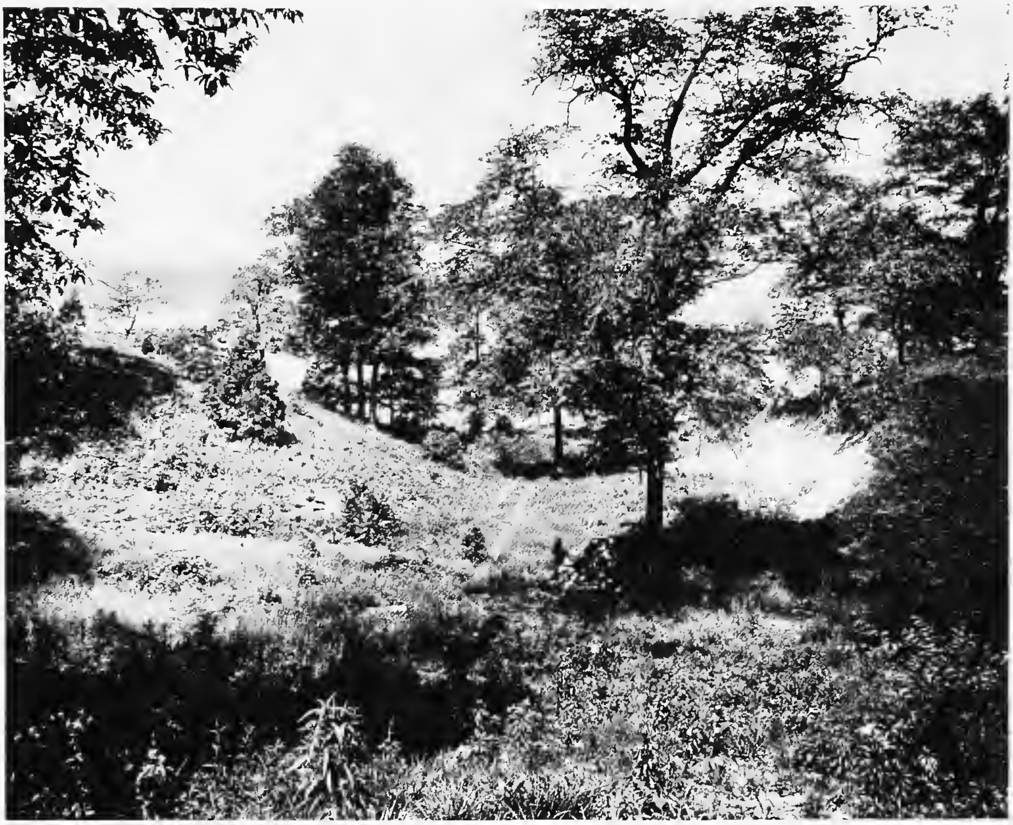
When it is realized that these ponds owe their existence to the impervious clay, beneath, holding back ordinary rain water, it will be seen that the quickest way to drain such a pond is to begin to dig in it, in the delusion that underground springs may be opened up.

Along the lower parts of the hollows, the soils often are favorable for cultivation. The northern half of Sleepy hollow, in the Delco Dell area, represents such an area, and the Old Orchard hollow, east of Moraine camp, is another. The sides and tops of the gravel ridges, however, suffer enormously from wash after plowing, and it would be for the best interests of the country if all of this gravel ridge land were removed from the area of cultivation. It will be a continual source of revenue only under two conditions: when covered with grass and used for pasturage, or when covered with trees and used for forestry.

76. The Interrupted Ridge, West of the Delco Ridge

In the Delco Dell area, two ridges stand out prominently among all those present. These are the Delco and David ridges. These ridges are separated by the Delco Dell and Sleepy hollows. The David ridge is steepest and best defined east of the Sleepy hollow. From its crest excellent views are to be had of the territory eastward and of the deep and long hollow westward. At two points, small gravel pits expose the arrangement of the sand and gravel in layers, an evidence that the ridges were formed by the action of running water. The Delco ridge is more interesting on account of the more varied character of the views toward the west. This varied character depends in large part on the presence of a series of short spurs extending westward from the Delco ridge. When these spurs are examined closely it will be seen that they terminate in parts more or less in alignment, as though parts of a formerly continuous gravel ridge, at present more or less interrupted by conspicuous gaps. For instance, west of the Kettering cottage, in the Delco Dell grounds, the spur is continued northward as a narrow ridge terminating in the flat fields, while southward it ends within a short distance abruptly at a gravel pit. By the way, in this gravel pit were found limestone pebbles containing fossils indicating that the pebbles consisted of Columbus limestone, probably derived, however, from exposures of this rock on the eastern shore of Lake Huron, in southern Ontario. Map on page 156.

The Chryst cottage stands on the crest of another western spur of the Delco ridge, but at its end it continues northward toward the gravel pit.



View of the gap in the frequently interrupted ridge west of the Delco ridge, as seen from a point between the Knopf and Funkhouser cottages. In the gravel pit on the right were found pebbles of Canadian limestone with fossils indicating that this limestone came from the northern extension of the Columbus limestone of Ohio.

a narrow gap intervening. This gap is seen best from any point of view between the Knopf and Funkhouser cottages. Farther south, the Ruthenburg cottage occupies the crest of another spur, and still farther south, at the southern end of the Big curve in the roadway, a ridge starts off in a southwest direction from the Bachelor's cottage, and is more or less in line with the end of a spur still farther south. The terminal parts of all of these spurs are sufficiently in line to suggest that they all may once have formed parts of a continuous ridge. This continuous ridge apparently was connected with the Delco ridge by numerous transverse ridges, representing short connecting drainage channels between the main north and south subglacial streams. In this case, the presence of the various gaps, interrupting the supposedly once continuous ridge, require explanation.

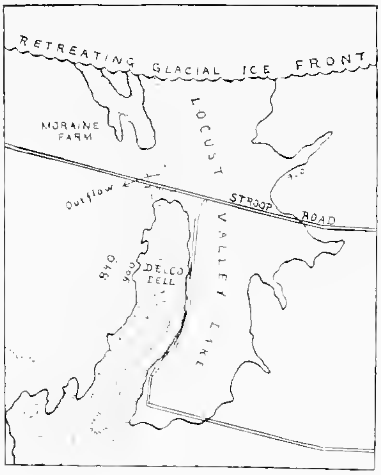
Before attempting an explanation for these gaps it may be well to call attention to similar gaps along the hill front extending from the Grand View farm southward toward Hole's creek. One of these gaps occurs at the eastern margin of the Emrick farm, about a quarter of a mile south of the Van Buren township line, but the most striking example occurs immediately north of this line. Here a deep and narrow valley descends northwestward and then opens through a gap in a more westerly direction into the flat plains beyond. At this gap the valley cuts through a steep ridge, readily followed southward, while northward lies the high ridge land forming the eastern edge of the Bradstreet farm. The spurs from the western edge of the Sunset ridge, northwest of Moraine camp, include toward the north a somewhat similar gap, but less evidently connected with the former presence of long gravel ridges, later almost entirely removed.

As a possible explanation of the various gaps here mentioned the following explanation is offered as at least possible. It is assumed that formerly the more or less continuous gravel ridges covered a larger territory than at present, especially immediately west of their present area of distribution. This is suggested by the abrupt termination of a part of the gravel ridge area west of the Cincinnati pike at its southern end, along the O'Neil road; also by the abrupt beginning of some of the gravel ridges along the various hill fronts south of the Stroop road.

At the time of melting back of the front of the glacial ice sheet, the melting may have been sufficiently rapid to have filled some of the depressions between the gravel ridges and to have caused temporary outflows of the imponded waters, laterally, across the points of lowest elevation presented along the crests of the ridges. These points of outflow later deepened and widened into gaps.

For instance, the watershed between the Locust farm and Kohl branch valleys, northeast and southeast of Delco Dell, at its lowest point is about 910 feet above sea level. See pages 204, 205. If, when the ice front had melted back about as far as the Moraine farm, north of the Stroop road, some part of the ridge then connecting the southern end of the East View ridge with the northern end of the Delco ridge had a lower elevation than 910 feet, an outflow of the imponded waters would have been started at this point of lower elevation and eventually might have led to the formation of the gap along the present Stroop road. At present this gap has been cut down to fully 100 feet below the crest of the highest parts of the ridges immediately north and south.

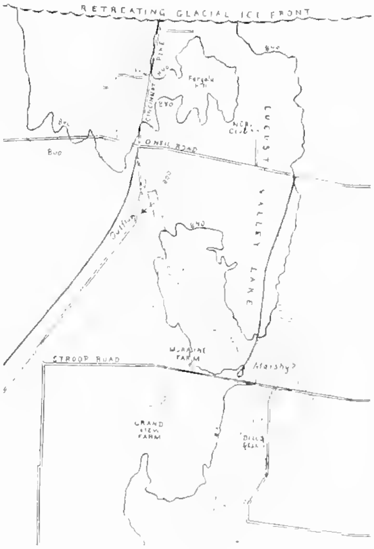
The highest part of the watershed between the Stroop creek drainage and the waters flowing northward toward the stream crossing the Governor Cox farm does not rise above the 850-foot level. Any waters impounded in the lower part of the Locust farm valley by a glacial ice front, which had retreated to a point north of the O'Neil road, would have found an exit westward through the Cox farm if any part of the gravel ridge here had at that time a lower elevation than 850 feet. At present, the base of the gap here stands at the 780-foot level, and only the highest part of the gravel hill immediately north of the brook on the Cox farm attains an altitude of 840 feet, so that it is not unlikely that in glacial times waters impounded northeast of the Moraine farm ridges may have found an exit across the northern part of the Cox farm.



Map of Delco Dell and Moraine farm, suggesting that the gap through the ridge area at Stroop road was caused by waters imponded east of the ridges overflowing at a point where the crest of the ridge area was lowest. The former connection of the ridge areas north and south of the gap is indicated by broken lines. The contour lines, 840 and 900 feet above sea level, are shown. Since the gravel ridges are believed to have been formed within a very brief interval of time, the supposed lake can not have been of long duration.

Possibly the gap through the Pike ridge, west of the Cincinnati pike, along the Nollman lane, had a similar origin.

It should be noted, however, that no washes of sands and gravels are noted at the outlets of these gaps of sufficient proportions to account for the material supposed to have been removed at these gaps. Possibly some of the meanders of the Miami river, when it skirted the foot of the gravel ridge area along the eastern margin of the Alexandersville flat lands, may account for this lack of corroborative evidence.



Map of Locust valley area, suggesting that the gap through the ridge area on the Governor Cox farm was caused by waters imponded east of the ridges overflowing at a point where the crest of the ridge area was less than 840 feet above sea level. The gap here was distinctly lower than at the Stroop road. The former connection of the ridge areas across the gap is indicated by broken lines. A part of the land covered by the earlier lake, along the Stroop road, is represented as forming marshy ground. This is merely imaginary.

77. Differences in the Direction of Trend of the Gravel Ridges in the Area South of Dayton

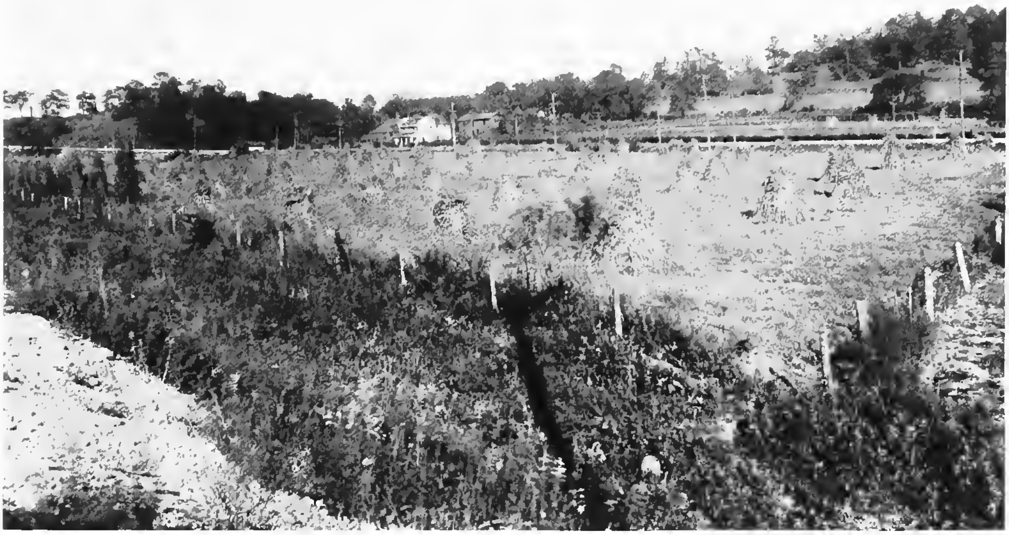
One of the most interesting features connected with the gravel ridges south of Dayton is their change in direction. For instance, south of the Van Buren township line the general trend of the gravel ridges is about 30 degrees east of south. This trend is seen best along the Schumacker and Walden ridges, southward, and along the western hill margin, where several minor gravel ridges may be detected. An isolated barn stands on the crest of the Walden ridge, in the midst of open fields, and the broad valley between the Schumacker and Walden ridges trends in a similar southeasterly direction, as far as the Rahn road.

North of the Van Buren township line, as far as the cottages in the Delco Dell area, the eastern ridges have a southwesterly trend. Between the Stroop road and the O'Neil road, their trend is approximately 30 degrees east of south. North of the O'Neil road, in the area west of the Cincinnati pike, their trend is almost directly south. In the Hills and Dales area, the trend of the Adirondack ridge is about 45 degrees east of south, while that of the Panorama ridge is almost the same as far south as Fair Forest, beyond which the trend becomes more southerly. Taking the region as a whole, the trends evidently are chiefly southerly and southeastward. The southerly directions are more nearly parallel to the general trend of the Miami valley in the immediate neighborhood, and the southeasterly directions are approximately parallel to the general direction of motion of the ice sheet, as indicated by the glacial striæ on the upper surface of the nearest exposures of solid rock.

At the Centerville quarry, five miles southeast of the Delco Dell, the direction of these striæ is 47 degrees east of south. At the abandoned limestone quarries west of Beavertown, three miles northeast of Delco Dell, their direction is 27 degrees east of south. Half a mile south of the Soldiers' Home grounds, their direction is 35 degrees east of south. From this it may be seen that those gravel ridges which have a more southeasterly course have a trend approximately parallel to the former direction of motion of the glacial ice sheet, at least during the closing stages of motion of the ice, at the time of retreat of the ice front. However, it is chiefly during this time of retreat, when the ice was most stagnant, that the gravel ridges are believed to have been formed.

78. The Termination of the Southern End of Some Gravel Ridges Against High Land

The gravel ridges are regarded as deposits formed by streams running in channels beneath the ice sheet. There are two features connected with these gravel ridges which demand explanation: one of these is the termination of some of these ridges southward against an area of high land, and



The gap through the gravel ridge area at the Governor Cox farm. The northern end of the ridge on the southern side of the gap is used as a gravel pit. The culvert along the Cincinnati pike, crossing the stream, is seen north of the house. The high hill on the left side of the view is supposed to have been connected formerly with the ridge on the right.

the other is the presence of several ridges in the same area extending approximately parallel to each other for long distances.

The first feature is well represented by the Adirondack and Panorama ridges, which trend southeastward and terminate in the high hill area in the southeastern part of the hills and dales. In a similar manner, the Grand View farm and Delco Dell ridges terminate southward in a high area extending along the Van Buren-Washington township lines. It is probable that the Walden and Schumacker ridges formerly extended southeastward across the present Rahn valley and connected with the high land southeastward. All of these occurrences suggest that the subglacial streams toward their points of exit from beneath the glacial ice built up their deposits

View of the western sides of the Chapel and Pike ridges, taken from the northwest. The house in the immediate foreground is the home of Mr. Sauerman.

until the bottoms of the stream channels rose to near the present level of the adjacent hill country. The high land would act as a barrier, checking the violence of the stream flow and favoring rapid deposition, until the stream bed was lifted to about the same level as the hill land.

In fact, it is probable that the gravel ridges were formed within a very short interval of time. It seems scarcely likely that even subglacial streams would long continue to flow on tops of steeply inclined gravel deposits, when by melting the bordering ice walls they could descend to lower levels. The higher and steeper the gravel ridge, the more likely it is to have been formed within a short period of time.

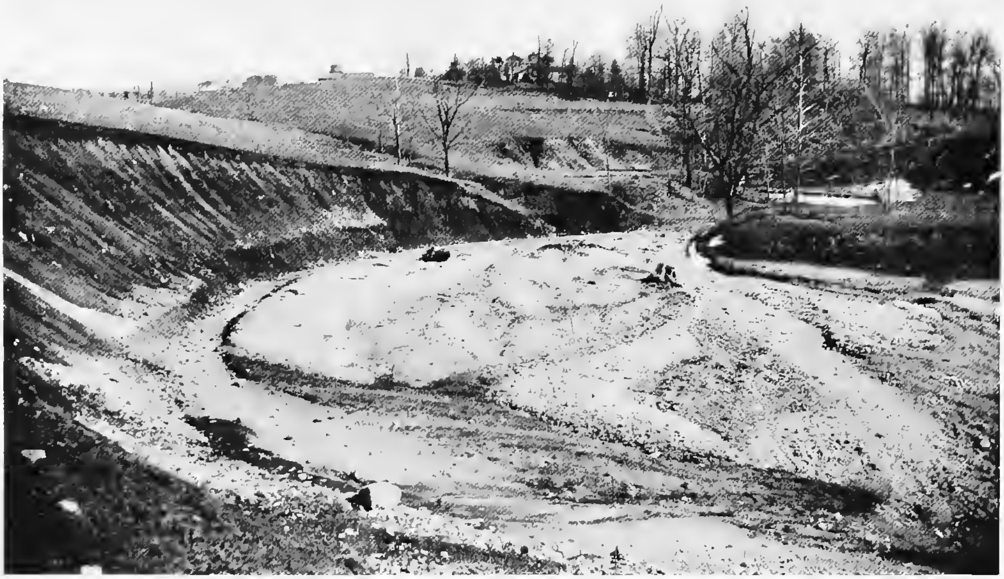
79. *The Presence of Parallel Ridges Within the Same Areas*

It is possible that the parallelism among the various gravel ridges may be due to large crevices produced by shearing in the glacial ice. It may be noted that the direction of motion of the glacial ice near the closing stages of the last glacial invasion, was approximately 30 degrees east of south in the area here under discussion, while the hill front along the Lebanon pike, against which the ice was thrust, had a direction approximately north and south. Hence there would be a tendency for the ice to be held back at relatively more northern points along the hill front, and to move ahead along relatively more southern points. This should produce shearing planes parallel approximately to the direction of motion of the ice. The more prominent of these shearing planes might develop, under the influence of subglacial waters, into crevices of sufficient size to permit the flow of fairly large-sized streams.

This widening of shearing planes into wide subglacial channels would be favored by a nearly stagnant condition of the ice sheet. An ice sheet moving forward with any degree of speed would tend to close up any crevices existing in the ice, so that if shearing planes should develop into crevices, these crevices would be likely to remain open only for short periods of time.

80. Changes in Direction of the Gravel Ridges Probably Caused by Changes in Direction of Flow of the Ice During Its Various Stages of Retreat

Different groups of gravel ridges may have formed at different times. For instance, the southeasterly trending ridges extending from the southern margin of Van Buren township to the hill land south of the Rahn valley may be among those earliest formed. Their direction is well defined only along their southern terminations. As the ice front melted back, the more southerly directed ridges in the Delco Dell area and on the Grand View farm may have been added, possibly during a more stagnant condition of the ice. Next, the more southeasterly directed ridges between the Moraine farm and the O'Neil road may have been formed, and finally the numerous more southerly directed ridges west of the Cincinnati pike may have been built up. The Adirondack and Panorama ridges, in the Hills and Dales area, may have been more or less contemporaneous in origin with the ridges between the Moraine farm and the O'Neil road.



View of stream east of Carrmonte, looking east toward the high ground in Oakwood. Note the ox-bow bends, and the effect of the wandering of the stream in producing more or less flattened territory. Something similar to this may have happened on a much larger scale in case of the Miami river valley. The deepest part of the channel in the immediate foreground is on the left, where the stream is cutting into the hillside, on the convex side of the curvature. On the concave side of this channel the gravel washed along by the stream from points farther up its course is deposited. Photographed in 1895, during a time when the stream had dried up.

In that case, it is possible to regard the confused area of hill land extending for fully a third of a mile north and for nearly the same distance south of the Van Buren-Washington township line as due to the overriding of glacial ice, with southerly directed stream channels, over a territory already covered with southeasterly directed gravel deposits or gravel ridges. Apparently the ice front stood at this point long enough to permit of a thicker and more widely distributed series of deposits than elsewhere in this immediate neighborhood. Hence the Van Buren-Washington township line marks the position of the watershed between the Locust Farm valley northward and the Schumacker farm valley southward.

This explanation regards the change in direction of the gravel ridges as connected with successive stages in the retreat of the ice front. It is not impossible, however, that the entire series of crevices over its total length of four and a half miles, may have been in existence at the same time so that all the deposits along the line of the present gravel ridges were going on simultaneously. There is no reason for believing that shearing could not produce a series of southeasterly directed crevices and of more southerly directed crevices in the same general area at the same time.

Only in case the deposits were made within a very short interval of time, however, could numerous approximately parallel subglacial channels be expected within the same area. Given, however, an abundance of rock and sand, the accumulations of many years of transportation by glacial ice, and a sufficiently rapid flow of an abundance of water, and all of the gravel ridges south of Dayton could be built up in a very short time.

These gravel ridges are not moraines in the sense that they have been deposited directly by the glacial ice, but they unquestionably consist to a large extent of actual morainal material reworked by running subglacial waters at the immediately ice front. In that sense of the term, these gravel ridges mark the terminal morainal area of one of the stages of retreat of the Wisconsin ice sheet. In other words, they form a local feature of the Germantown division of the Dayton moraine.

81. The Western Gravel Ridges in the Area Between Delco Dell and Hole's Creek

The two most conspicuous gravel ridges in the southern part of the area north of Hole's creek are the Schumacker and Walden ridges. The Schumacker ridge is wooded, but most of the Walden ridge is fully exposed in the open fields. A deep broad valley separates these ridges southward, but northward, along the high ground, the ridges are only indistinctly defined. The Schumacker ridge may be traced as far as the eastern side of the gully on the old Eby farm, directly north of the line between Van Buren and Washington townships. A parallel and much more conspicuous ridge forms the western side of this gully and is interrupted by a gap near the northeastern corner of the Emerick farm. The gap may be reached readily by following the Delco ridge southward through the woods as far as the open fields and then crossing the latter straight westward to the high ridge forming the western boundary of the high gravel area. The gap is located a short distance north of the farm road crossing this ridge.

Near the old abandoned barn on the top of the Walden ridge the latter divides into two branches southward. Northward this ridge may be traced to the big gap east of the farmhouses on the Emrick farm. Here it forms the high land along the fence forming the eastern boundary of the farm. See pages 204, 205.

The Emrick ridge, farther westward, extends from the Emrick farm houses southeastward in a direction parallel to the Walden ridge. It is an excellent illustration of an interrupted ridge, but on a much larger scale than the interrupted ridge in the western part of the Delco Dell grounds. It is intersected by numerous gaps and in the area directly west of the old abandoned barn on the Walden ridge it is intersected by the conspicuous washed gully which is one of the best illustrations of the danger of removing the protective covering of grass and shrubs from a steep hill side. This washed gully lies south of the road leading northeastward up the hillside from the Walden homestead. West of the southern end of this interrupted Emrick ridge several additional small gravel ridges may be seen. All of these ridges have a southeasterly and approximately parallel direction. While much less sharply defined, as a rule, than the ridges farther northward, especially those west of the Cincinnati pike, they evidently had the same origin, and prove the former presence here of subglacial streams.

The southern end of the kame area west of the Cincinnati pike, as seen from the Ohio Electric railroad southwest of the Governor Cox farm. The most eastern hill, on the right, is the southern end of the Pike ridge, at the sub-power station. View taken across the flat lands of the Miami. The southern end of these more western ridges appears to have been cut off by a former ox-bow bend of the Miami river.

82. *The Ox-Bow Bends of the Miami River*

One of the most conspicuous ox-bow bends of the Miami river is presented by the old river channel north of the bluffs between Oakwood and the western margin of the Calvary cemetery. It is probable that the gravel ridges west of the Cincinnati pike once extended farther northward, into the broad Miami valley, but in that case the northern ends of these ridges evidently were removed by the wash of the river.

Possibly the abrupt termination of the more western gravel ridges, west of the Cincinnati pike, north of the O'Neil road, may have been due to a similar ox-bow bend of the river toward the close of the glacial period. Apparently this ox-bow bend truncated not only the southern ends of the more western gravel ridges north of the O'Neil road, but also the northern ends of the ridges on the Grand View farm. It can not be said that the evidence of such a former ox-bow bend in the Miami river is at all clear, but its presence is suggested by the general contour of the western margin of the gravel ridge area, where it adjoins the flat bottom lands of the Miami valley.

Evidently the Miami river has been a great traveler. Northwest of Oakwood it carved out a path considerably toward the east of a direct channel and at the Pinnacles it follows a path considerably west of a direct line. Evidently these ox-bows are of much more recent date than the hypothetical one south of the O'Neil road.

The southwestern margin of the gravel ridge area, viewed from the Bellbrook road. The abandoned barn on the top of the Walden ridge is seen at the extreme right. The gap through the western ridges east of the Emrick farmhouses is located at the extreme left.

CHAPTER XII

THE THICKNESS OF THE DRIFT DEPOSITS IN THE AREA SURROUNDING DAYTON

83. Solid Rock Beneath a Thin Covering of Soil

Some parts of Montgomery county are remarkable for the frequency with which solid rock is exposed beneath a very thin covering of soil.

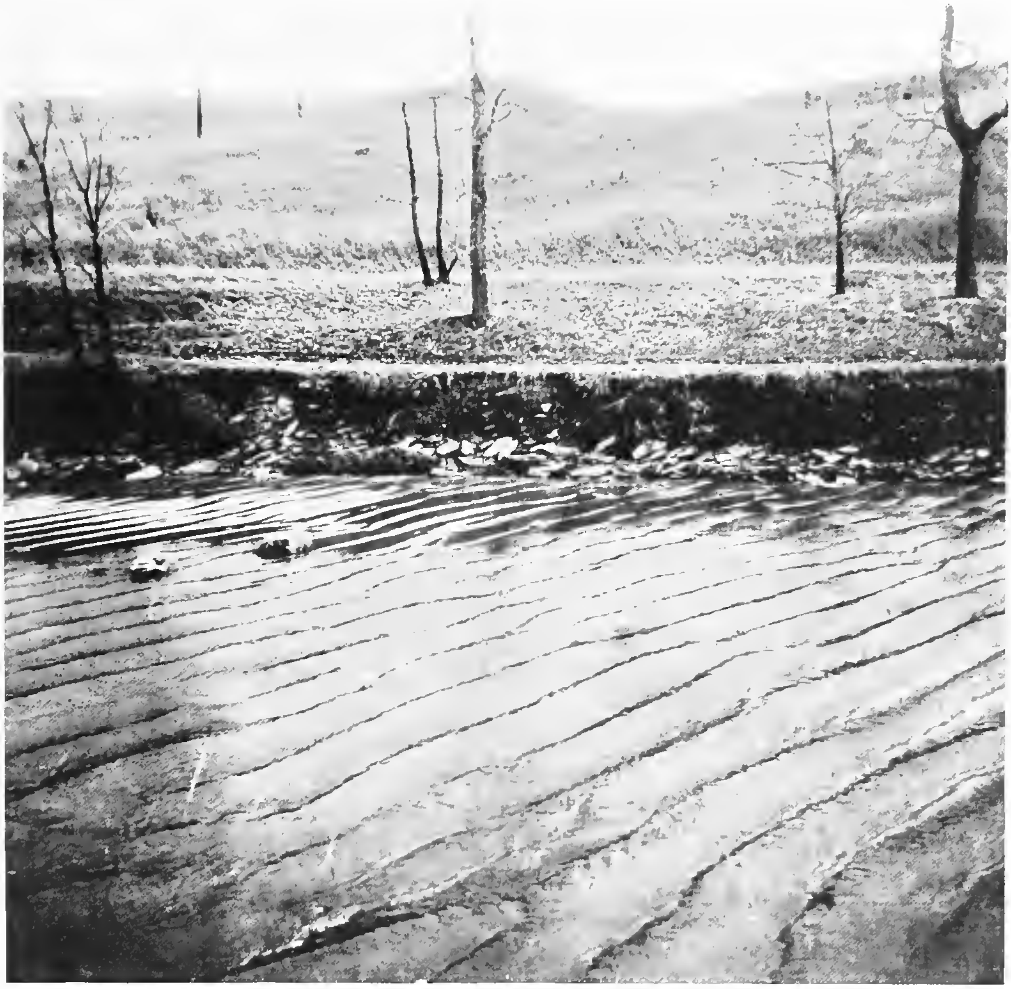
For instance, in the area extending from a mile south of the Soldiers' Home northwestward toward Trotwood and Amity the rock frequently is covered by only 2 to 5 feet of soil. Along the stream courses, and along the brows of the hills, exposures of rock are frequent. The exposures consist chiefly of the Brassfield limestone, and of the overlying divisions of Silurian limestone. The Springfield limestone frequently is exposed in quarries opened for building stone. Here usually less than 5 feet of soil is removed in order to get at the solid rock.

Even in those parts of the country in which the rock does not appear at the surface, solid rock may be present within a short distance from the top of the soil. For instance, in the area extending from Amity westward, through Pyrmont, to the western border of Montgomery county, no rock exposures are known, but rock is struck at a moderate depth in wells, and several quarries formerly were in operation. Two miles west of Amity, in the middle of section 15, rock was struck in a well within 6 feet of the top of the soil, and a quarry formerly was in operation south of the road. Three-quarters of a mile westward, another quarry formerly existed, and a third quarry was located south of the road, a mile east of Pyrmont, along a stream channel. From Pyrmont southwestward there is a rather thick deposit of soil and of glacial deposits covering the rock, wells 30 to 50 feet deep not reaching the same, but a mile north of the Dayton-Eaton pike, on the Montgomery county line, the Brassfield limestone is exposed in the creek bed. The quarries between Amity and Pyrmont were opened up in rock belonging to the Springfield or overlying divisions of the Silurian limestones.

Rock lies close to the surface of the soil also in the area west of the Stillwater river, between Englewood, West Milton, and Ludlow Falls, and from Englewood eastward toward Chambersburg. It lies close beneath the surface also west of the Miami river, at various localities on the high ground between Tadmore, Tippecanoe, and Cowlesville. It is covered by a comparatively thin layer of soil also east of the Miami river, from a point 2 miles north of West Charleston southward for 7 miles, and thence eastward toward Brown station, Brandt, and Huffeysville.

About a mile north of Belmont, southeast of Dayton, the solid rock is close to the surface of the soil, but in the quarries formerly operated southeast of the asylum and at Beavertown it was covered by about 20 feet of sand, gravel and clay.

It should be noted that in all of these cases in which the solid rock is found beneath a thin cover of soil, this soil consists chiefly of clay. It evidently represents a glacial till deposit. The underlying rock surface usually is distinctly striated, and the till deposit apparently represents whatever material happened to be embedded in the bottom of the ice during the

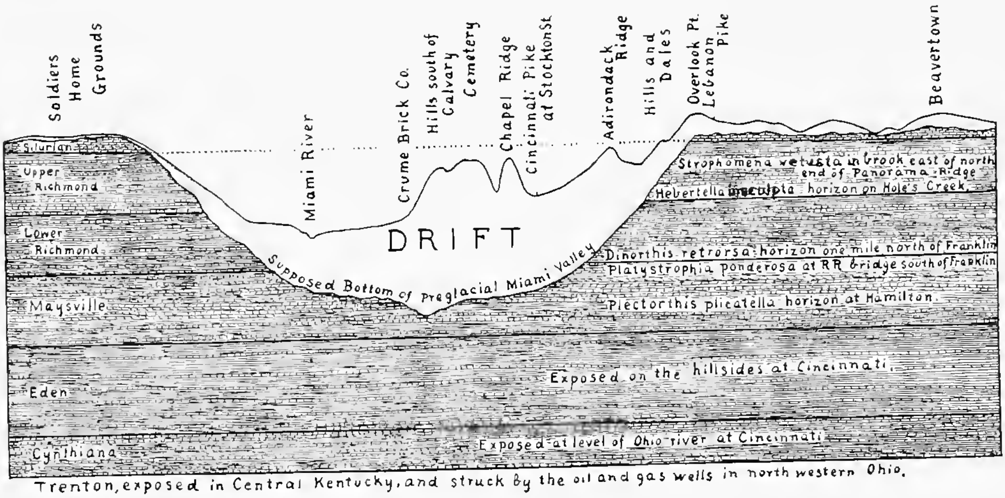


Ripple-marked surface of limestone, belonging to the Richmond group; exposed about a mile east of Winchester, Ohio. Similar ripple marks are common on the limestone layers 5 miles west of Middletown, a mile south of Jacksonburg.

final stages of the melting of the glacial ice. It is not a deposit from the margin of the glacial ice sheet, but from its bottom. In this sense, it might be called a ground moraine, rather than a terminal moraine deposit.

It will be noticed that all of these areas, in which the rock lies close to the surface of the soil, occur on the higher levels of land, not in the valleys. In Montgomery county, this is equivalent to saying that the thin soil covers are found chiefly on Brassfield, Dayton, Springfield, or Cedarville limestone, or on some other division of the Silurian group of rocks, since these rocks underlie all of the high levels in the county. Since they are harder than the underlying Cincinnatian strata, and are less readily eroded, they frequently form the brows of the hills and the margins of the flat hill lands bordering the deeper valleys.

Glacial deposits are likely to be thinnest where the glacial ice was pushed up over the brow of a hill on rising from a fairly deep valley. This accounts for the numerous exposures of the Brassfield and overlying Silurian limestones along the hill front south of Wolf creek, from the vicinity of the Soldiers' Home to a point 3 miles southeast of Brookville. On the northern side of this valley, exposures are few. While rock exposures are common along the hill front east of the Miami river, from a point southeast of Tippecanoe to beyond Tadmore, and thence eastward both toward New Carlisle and Huffeysville, no outcrops are known along the eastern front of this hill land, between Huffeysville and a point two and a half miles southwest of New Carlisle. Along the margin of the large triangular mass of hill land beginning two and a half miles east of Dayton, east of the Montgomery county line, rock exposures are almost unknown ex-


Soldiers Home Grounds
Miami River
Crume Brick Co.
Hills south of Calvary Cemetery
Chapel Ridge
Cincinnati Pike at Stockton St
Adirondack Ridge
Hills and Dales
Overlook Pt. Lebanon Pike
Beavertown
Silurian
Upper Richmond
Lower Richmond
Maysville
Eden
Cynthiana
DRIFT
Supposed Bottom of Preglacial Miami Valley
Strophomena vetusta in brook east of north end of Panorama Ridge
Hebertella insculpta horizon on Hole's Creek.
Dinorthis retrorsa horizon one mile north of Franklin
Platystrophia ponderosa at RR bridge south of Franklin
Plectorthis plicatella horizon at Hamilton.
Exposed on the hillsides at Cincinnati.
Exposed at level of Ohio river at Cincinnati
Trenton, exposed in Central Kentucky, and struck by the oil and gas wells in north western Ohio.

Vertical section from Beavertown to Soldiers' Home, across the Miami valley, indicating that the gravel ridge area in the Hills and Dales and south of Calvary cemetery lies chiefly below the level of the hills bordering the preglacial valley. The drift filling the valley consists chiefly of gravel; that on the hill tops is chiefly till. The underlying rocks and the horizon of a few of the characteristic fossils also is indicated. Localities where the same rocks and fossils may be found freely exposed on going from Dayton toward Cincinnati are mentioned. The present valley of the Miami river is that part lying west of the hills at the Crume Brick Company plant.

cept along the northwestern margin, extending from New Germany northward. It should be remembered that the ice sheet in Montgomery county moved about 15 degrees east of south, and hence the northwestern boundary of any hill land was the part which bore the brunt of the thrust of the ice sheet during its motion in a general direction southward.

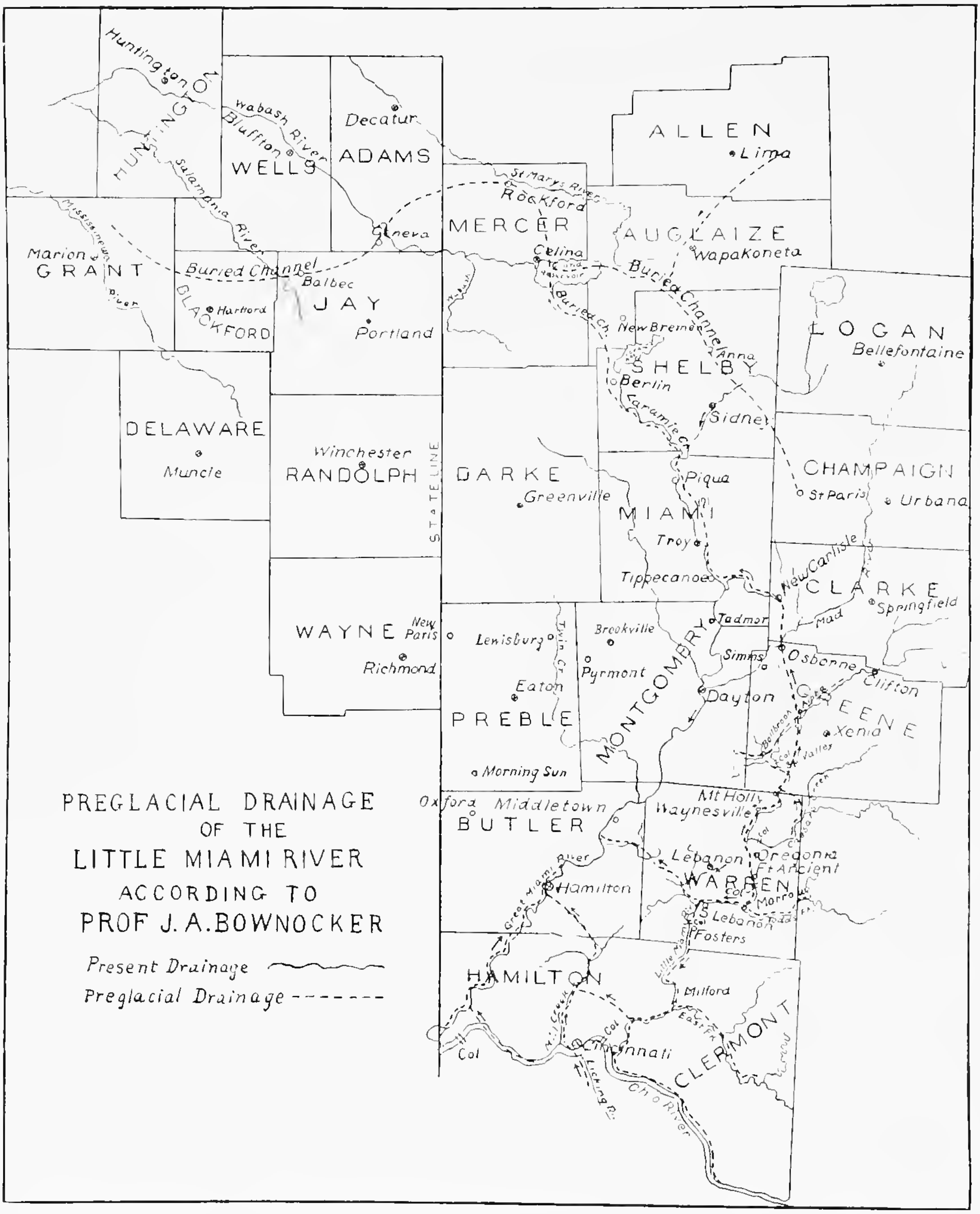
Where the ice sheet crossed a comparatively narrow and deep valley, the rock along the top of the hill land west of the valley is also likely to be covered by little soil, apparently owing to the downward flexure of the ice sheet. Such an area occurs west of the Stillwater river, between Englewood and Ludlow Falls, and more isolated localities occur west of the Miami river, near Tadmor, half way between Tadmor and Tippecanoe, and northwest of Cowlesville.

84. Thick Deposits of Gravel, Sand, and Clay Beneath the Flat Lands Occupying the River Valleys; and the Preglacial Drainage of Southwestern Ohio

It is a familiar fact that at many localities wells have been dug or bored through considerable thicknesses of gravel, sand, and clay without striking solid rock. What is not familiar to the average observer is that, no matter how thick the overlying deposit of gravel, sand, and clay may be, there always is rock beneath. In other words, the interior of the earth consists of solid rock. The gravel, sand, and clay forms merely a relatively thin coating which covers this rock interior.

Since, in glaciated areas, these deposits of gravel, sand, and clay were transported chiefly by the glacial ice or by the streams issuing from its front, they commonly are known as drift. Naturally this drift is thickest in the deeper preglacial river valleys. Hence, in order to get some idea as to the general appearance of these preglacial valleys it is necessary to determine to what extent they have been filled with drift and then to imagine how they would appear if all of this drift were removed.

Within the valley of the Miami river the following thicknesses of drift have been found beneath the comparatively flat lands bordering the present river channel. Near Piqua, the thickness of the drift, down to the solid



PREGLACIAL DRAINAGE OF THE LITTLE MIAMI RIVER ACCORDING TO PROF J. A. BOWNOCKER

rock, is 170 feet; at Troy, 133 feet; at Osborn, 207 feet; in Dayton, at the corner of First and Findlay streets, 247 feet; at Miamisburg, 181 feet; and at Hamilton, 210 feet. The thickness of the drift at Osborn is included in this brief list since, in preglacial times, the channel of the Miami river is believed to have extended from Troy toward New Carlisle and Osborn, rather than by way of Tadmor and Taylorsburg, as at present.

If now the elevation above sea level of the various towns here mentioned be determined, and if from this the various thicknesses of drift be subtracted, in order to ascertain approximately the elevation of the river bottom at each locality during preglacial times, the results are between 700 and 720 feet for Piqua, 700 feet for Troy, and 600 feet for Osborn. This lower elevation for the preglacial river channel at Osborn certainly does not favor a northward flow of the Miami river, from Osborn toward Troy, in preglacial times, as sometimes supposed.

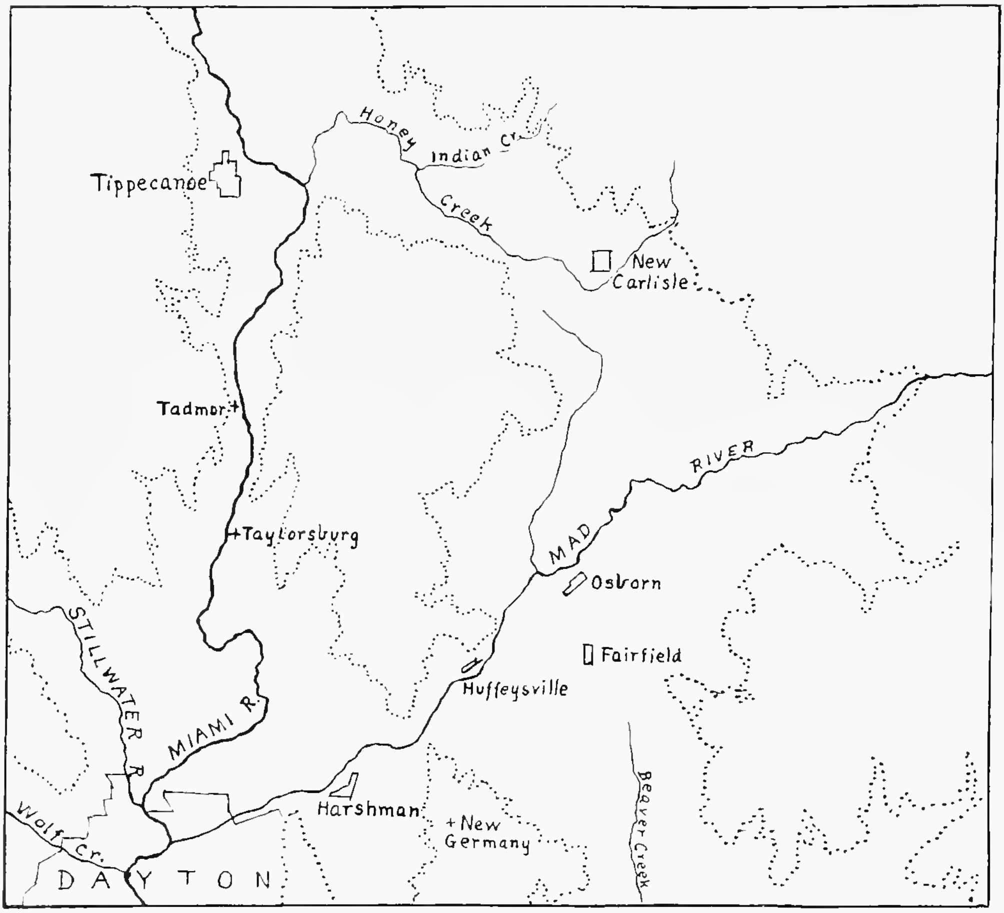
From Dayton southward the corresponding results would be 520 feet at the corner of First and Findlay streets in Dayton, 520 feet in the northern part of Miamisburg, and 380 feet for Hamilton. These data also suggest a southward flow of whatever stream occupied this part of the Miami valley in preglacial times.

It is reported that at St. Paris, 16 miles east of Piqua, a well was sunk a distance of 530 feet without striking rock. At a depth of 400 feet large pieces of wood and of bark and fragments of mussel shells were struck. The bottom of this well was approximately 685 feet above sea level. The bottom of the preglacial valley evidently was still lower, but its actual elevation is unknown. Since the bottom of the preglacial valley at Piqua is somewhere near 700 or 720 feet, it is evident that the bottom of the preglacial valley struck at St. Paris is lower. Whether this necessarily means a northward flow of the preglacial streams at Piqua and St. Paris I am not prepared to state.

Professor John A. Bownocker, the present state geologist, gave this subject more detailed attention, and in 1900 published the map here reproduced. In this map the word "col" designates those narrow parts of the present river channels at which in preglacial times the drainage areas of neighboring basins were separated. In other words, at these points, in preglacial times, the streams flowed in opposite directions. According to this map, in preglacial times, the upper part of the Ohio river and the Licking river joined northwest of Cincinnati and flowed toward Hamilton. That part of the present little Miami river which lies south of Foster, connected with the same drainage basin. Todds Fork, and that part of the present Little Miami river lying between Fort Ancient and Foster drained westward into the broad valley now connecting with the Great Miami river valley south of Middletown. Here it was joined by the drainage of the Great Miami river valley from points at least as far north as Taylorsburg and Harshmanville. The remainder of the Little Miami river, from Fort Ancient northward, flowed northward by way of Alpha, Osborn, New Carlisle, Tippecanoe, Troy, and Piqua toward the headwaters of the Wabash river, being joined by the preglacial river passing through St. Paris somewhere in northern Ohio. According to the map this junction took place near Celina.

The reasons for assuming these directions for the preglacial drainage of southwestern Ohio are given by Professor Bownocker in his paper on the History of the Little Miami River, published by the Ohio State Academy of Science. For our present purpose it will be sufficient to call attention to the fact that the map leaves unsolved as to what becomes of the Ohio and Licking river drainage after reaching Hamilton, and of the Todd Fork drainage after reaching the vicinity of Middletown. Evidently the map is intended to suggest that the outlet for this drainage must be toward the northwest, but that the precise path for this outlet has not yet been determined. In the search for such an outlet it is interesting to note that exposures of rock ranging from the Brassfield limestone to the Springfield limestone are so frequent and the overlying soil is so thin in the area between the Soldiers' Home and that part of Wolf creek which lies three miles southeast of Brookville that the possibility of any considerable preglacial valley through this region may be discounted. Farther west, Silurian limestone is struck by wells at shallow depths at various localities as far west as the creek one mile east of Pyrmont, and three quarries were formerly in operation, one at the eastern margin of section 15, one near its western margin, and a third along the creek one mile east of Pyrmont. Within this more western area the top of the solid rock averages about 990 feet above sea level. At Pyrmont, wells 50 feet deep do not reach the rock; but 50 feet below town level is still 990 feet above sea level. The drift continues heavy between Pyrmont and the valley of Twin creek, four miles westward, but Brassfield limestone is exposed at the 960-foot level four miles southwest of Pyrmont, along the Montgomery county line. Between Lewisburg and Eaton exposures of the Brassfield and overlying limestones are too numerous to make the former presence of a preglacial channel within this area probable. Between Eaton and Richmond there are a sufficient number of exposures of Brassfield limestone and of the immediately underlying parts of the Richmond group to eliminate this part of the territory also from a possible course of a preglacial outlet for streams flowing from the direction of Hamilton and Middletown. Since the line of Brassfield outcrops from Eaton reaches the southern border of Preble county southeast of Morning Sun, within seven miles of the Indiana state line, it is evident that the preglacial channel must be sought within the limits of Butler county. Here, however, numerous exposures of Richmond strata intervene to points considerably beyond Oxford. It is probable that the basal parts of the Richmond formation are continuous as far as the areas immediately west of the southwestern corner of Butler county. When it is realized that the rock beneath the preglacial valley at Hamilton is struck somewhere near the 380-foot level above sea and that the basal layers of the Richmond west of Hamilton are at least 775 feet above sea level, the difficulties of finding a preglacial outlet in this direction may be appreciated.

For the present, therefore, we are obliged to conclude that a westward drainage of preglacial waters from the region of Hamilton and Middletown through Butler, Preble, or Montgomery counties, seems highly improbable. In the meantime it must be acknowledged that such a map as that prepared by Professor Bownocker for the drainage of the Little Miami river, especially of its upper waters, is highly stimulating to further research. It emphasizes the separation of the drainage of that part of the Miami river which lies north of Tadmor and of that part of the Mad river which lies east of Simms station from the general drainage of the Miami river from Dayton southward, and places the main channel along Alpha, Beaver creek, Osborn, New Carlisle, and Tippecanoe. This was regarded as the preglacial channel of the upper waters of the Miami also by Professor Edward Orton, in his reports on Clarke and Miami counties, published



Map contrasting the width of the pre-glacial valley extending from Tippecanoe by way of New Carlisle, Osborn and Fairfield toward Beaver creek with the present channel of the Miami river at Tadmor. The high ground bordering the valleys is outlined by dotted lines.

more than 25 years earlier. Orton, however, at that time thought that the drainage through this preglacial channel was southward.

85. The Huffman Prairie Area

The argument in favor of the separation of the drainage of the Miami river north of Tadmor and of the Mad river east of the Montgomery county line, during preglacial times, from that part of the Miami river which extends southward from Dayton is chiefly based upon the narrowness of these river channels at Tadmor and at the Montgomery county line, and on the comparatively shallow depth at which the underlying rock is believed to occur. Since a much wider valley, covered with thicker masses of drift occurs farther eastward, and since connection with this valley appears unobstructed, the former drainage is considered to have followed the wider and deeper more eastern preglacial drainage basin, rather than the present channel.

South of Tippecanoe, the valley of the Miami river narrows rapidly as though approaching the headwaters of some stream, instead of doing the exact opposite. At Tadmor, the high rock walls on the two sides of the valley are only three-quarters of a mile apart at the top, and near their base the underlying strata approach each other within half a mile. Southward, this narrow gorge continues for about a mile and then it widens out rapidly again, south of Taylorsburg. To the student of physical geography the topography here resembles that of two former stream valleys flowing in opposite directions from some point between Tadmor and Taylorsburg.

East of Tippecanoe, however, there is a very broad preglacial valley, occupied at present only by an insignificant stream, Honey creek, and south of New Carlisle the continuation of this broad valley is drained by a stream not even large enough to receive a name. Along this eastern preglacial channel the rock walls are at least two miles apart.

This ancient preglacial valley at present is deeply filled with gravel, sand, and till deposits. The highest part of the watershed separating Honey creek from the little stream flowing southward toward Osborn is located southwest of New Carlisle and is 870 feet above sea level. If, after the melting back of the glacial ice front the waters imponded in the areas south and southeast of Tippecanoe found a lower outlet along the watershed between Tadmor and Taylorsburg than 870 feet, they would have taken this western channel in place of the former eastern preglacial valley. In the course of time the watershed between Tadmor and Taylorsburg would be cut down to its present level.

In a similar manner, the channel of the Mad river at the eastern margin of Montgomery county occupies a valley only about half a mile in width, while in both directions from this point the valley widens rapidly. Since the watershed between the Mad river and Beaver creek, 2 miles southeast of

Osborn is 850 feet above sea level, the waters covering the Huffman prairie area southwest of Osborn would cut through a new channel by the present exit from the prairie area only if they found the western watershed below the 850-foot level. At present the hill tops bordering the western exit rise to the 920-foot level, but between these hill tops there may have been a depression descending to less than 850 feet, in preglacial times.

If the Mad river, during the late glacial times was obliged to cut for itself a new channel through the hill-front along the eastern line of Montgomery county, west of Simms station, then for a time the waters might have been imponded in the Huffman prairie area extending from Medway, Osborn and Fairfield southwestward. Even in comparatively recent years all of this area was very marshy, and if it were not for the extensive drainage ditches, most of it would be marshy to-day. Water is struck within moderate distances of the surface of the ground, and the total quantity present in the thick deposits of underlying sand must be enormous.

86. *Sands and Gravels as a Source of a City Water Supply*

It would be interesting to determine to what extent Dayton has access to the enormous quantities of water present in the sands and gravels underlying the Huffman prairie area, east of the Montgomery county line. At present our water is withdrawn from a narrow area extending from the vicinity of the waterworks, within the limits of Dayton, along the Mad river as far east as the point where the river is crossed by the Erie railroad, north of the northern extension of Huffman hill. This point lies 3 miles southwest of the gap by means of which the Mad river leaves the Huffman prairie area. Of course, at present we are securing chiefly such water as seeps from the bed of the Mad river downward through the underlying sands and gravels. No attempt is made to secure any of the water outside of this stream channel, and the upper wells, of course, tend to exhaust those farther down the stream. Running river water from the dam at Findlay street through the canal into the old Bimm ice pond of course adds to the water supply of the wells in the vicinity of the pond since the water naturally will seep through gravel and sand quicker when under greater pressure, and this increase in pressure will be proportionate to the height of the water in the pond over the top of the water surface in the river. The bottom of a pond acts virtually as a filter, and it becomes a question whether such a filter within the confines of a city and subjected to all of the possibilities of contamination is advisable. Sooner or later it may become necessary to consider the erection of an extensive artificial filtering system.

Pumping naturally reduces the level of the water in the wells below that of the water in the immediately surrounding territory, and hence the water from this surrounding territory seeps through the sand and gravel toward the wells. Most of this additional water comes, of course, from the river channel, directly above, and this is the only reason for placing all of the wells so close to the river. The seepage of water through sand and gravel is so slow that, for a large supply, it is necessary to depend upon a supply close at hand, requiring a minimum distance for seepage.

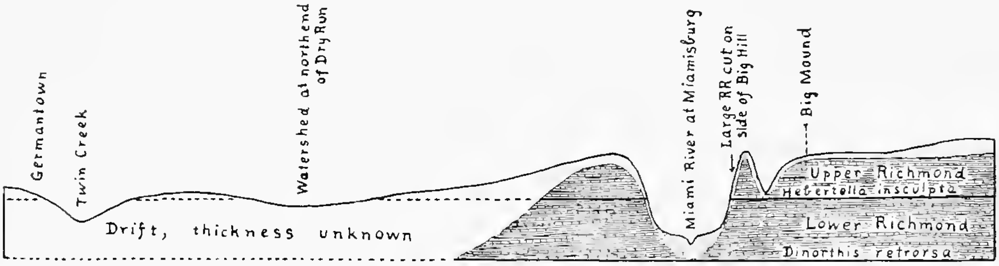
Seepage through sand and gravel is supposed to free the water from dangerous germs. The effectiveness of this form of filtering might readily be called in question, although all reports on the water supply of Dayton hitherto have been very favorable.

The rate of flow of water within sands and gravels, of course, is very slow. Some people seem to think that there are underground streams running along channels comparable with those flowing through the underground passages of caves. Nothing could be farther from the truth. The largest underground channels that exist in sands and gravels are the small spaces present between the sand grains and the pebbles, as exposed in any open sand or gravel pit.

The direction of flow or seepage of underground water, in general, is practically the same as the direction of flow of the river water, down the valley followed by the stream, excepting in so far as there also must be a lateral seepage from the higher land along the valley toward the river channel. In a similar manner water must seep from the surrounding land toward any active well, since the water in the latter represents a low level, on account of the continual withdrawal by pumping.

Wells placed in a series along a river channel attack chiefly the same source, that part of the river water which sinks into the sands and gravels from the overlying river bed, excepting as new supplies come in much more slowly from the sides of the valley. Hence the importance of keeping track of the sanitary conditions not only in the immediate neighborhood of the wells, but also up-stream and also for a considerable distance from the river margin.

The adequacy of any water basin as a source of supply is also a problem. So far we have been tapping merely the supply of water furnished by the flat lands along the Mad river, extending from within the boundaries of the city as far eastward as Harshmanville. It is a question to what extent the withdrawal of the water from the wells recently opened up in the vicinity of Harshmanville will add permanently to the water supply at Dayton, and to what extent it will lessen the waters furnished by the wells farther down stream, in the vicinity of the waterworks.

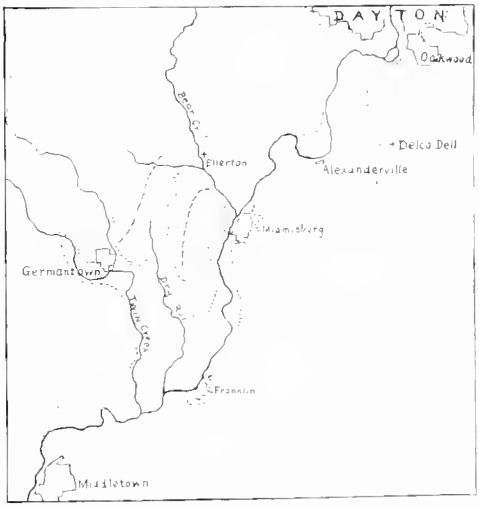


Vertical section from the hills east of the southern end of Miamisburg to Germantown, indicating the narrowness of the valley at Miamisburg. The same vertical scale is employed as for the section through the Hills and Dales area. A pre-glacial valley is supposed to exist beneath the drift deposits in the Dry Run valley, but as a matter of fact the thickness of the drift here is unknown. However, no exposures of rock are known between Carlisle and Germantown, within two miles east of Twin creek, nor from the wide area between Germantown and Ellerton, nor between Ellerton and Alexandersville.

Farther eastward, in the Huffman prairie region, there is, of course, a large supply of water, hitherto practically untouched. Although apparently merely an area farther up the same river basin, the Huffman prairie area in reality represents geologically a quite distinct basin, connected with the flat land surrounding Harshmanville only by a comparatively narrow channel, along which the seepage channel of sand and gravel appears to be of only moderate depth. This channel, two miles northeast of Harshmanville, apparently leaves untouched all excepting the highest levels of the water, which is seeping through the Huffman prairies, so that the latter offer great sources of additional supply for the growing needs of the city. Wells sunk in the vicinity of Simms station or the Wright aviation field would attack a distinctly new source of supply.

87. The Alexandersville Bottom Lands

The present channel of the Miami river, at Miamisburg, is remarkably narrow and steep-sided, compared with the general width of the valley both north and south of the town. At the southern end of Miamisburg, the hill cut by the Big Four railroad is only about half a mile distant from the nearest part of the hill-front on the western side of the present river channel. However, 3 miles west of Miamisburg is a much wider preglacial valley, at present deeply covered with drift and occupied only by an insignificant stream, Dry run. The headwaters of Dry run are separated from that part of the Miami river valley which lies west of Alexandersville and West Carrollton by a watershed which is about 770 feet above sea level. At present, the hills at the narrow part of the valley at Miamisburg rise 900 feet above sea level. Therefore, if the channel through Miamisburg was not open in



Map contrasting the width of the valley of the Miami river at Miamisburg with the valley farther northward and southward. The high ground bordering the valleys is outlined by dotted lines. The hypothetical pre-glacial valley east of Germantown, supposed to be the pre-glacial path of the Miami river, is indicated by broken lines. At present this path is heavily covered with drift.

preglacial times, it must have been at least below the 770-foot level, if resulting from the escape of imponded waters.

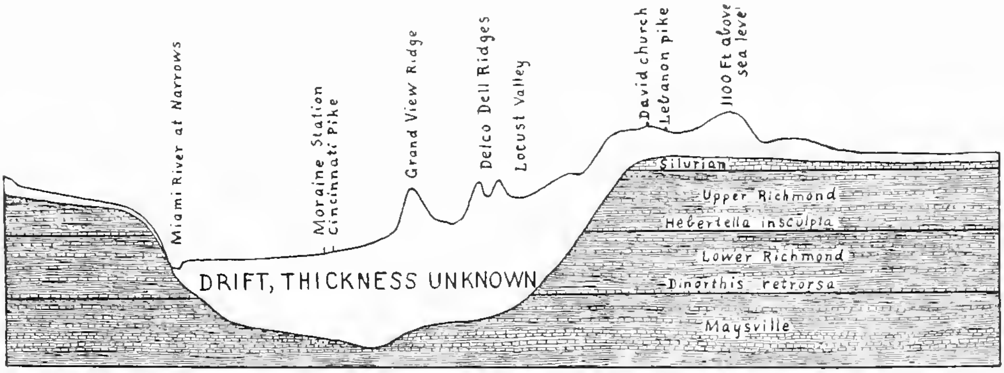
North of Miamisburg, the bottom lands of the Miami river are remarkably flat and cover wide areas. These are the Alexandersville flat lands, which extend northward as far as Dayton. Topographically, they correspond to the Huffman prairie area, east of Dayton.

The most northern rock exposure along the hill front northwest of Miamisburg occurs about a mile from town. No exposures are known from the broad area extending from West Carrollton westward toward Ellerton, and beyond, to the headwaters of Dry run. No exposures occur moreover from this point southward, along the preglacial valley occupied at present by Dry run, excepting on the western side of Twin creek, south of Germantown. Hence, the former use by the Miami river of the channel by way of Dry run, instead of by way of the present channel through Miamisburg is regarded as not improbable.

88. Thick Deposits of Gravel and Sand Above the Level of the Flat Lands in the River Valleys

In addition to the thick deposits of drift underlying the flat bottom lands bordering the rivers in the existing valleys, there are considerable thicknesses of gravel and sand also above the level of these bottom lands, especially along the sides of the preglacial valleys. This is to be expected, since gravel and sand are stream deposits, and stream deposits are to be expected in valleys, rather than on the hills.

The peculiar conditions under which streams issued from the margin of the glacial ice sheet caused some of these streams to build up gravel and sand deposits on high land. For instance, west of the northern end of Catalpa drive, north of Dayton, there is a short gravel ridge, which at its highest point rises 70 feet above the glaciated top of the Brassfield limestone, and forms one of the conspicuous landmarks in this area. At present this ridge is being exploited for sand and gravel, and in a short time the highest part of the ridge, rising in the form of a steep knoll, will have been removed entirely. This ridge probably represents the deposit of a subglacial stream, near the margin of the ice sheet, and therefore had a history similar to that of the gravel ridges south of Dayton, here under discussion. Its chief interest lies in the fact that this subglacial stream evidently found an exit from beneath the ice sheet at higher levels than usual.



Vertical section from David church to the Narrows, four miles southwest of Dayton, across the Delco Dell gravel ridge area and the Miami valley. The present valley lies west of the Grand View ridge area. In pre-glacial times the valley probably extended as far east as the David church. The gravel ridges in the Delco Dell and Grand View areas lie below the level of the hills bordering the pre-glacial valley. The thickness of the drift filling the valley is unknown. The drift deposits within the pre-glacial valley are chiefly gravel, those on the hills bordering the valley are chiefly till.

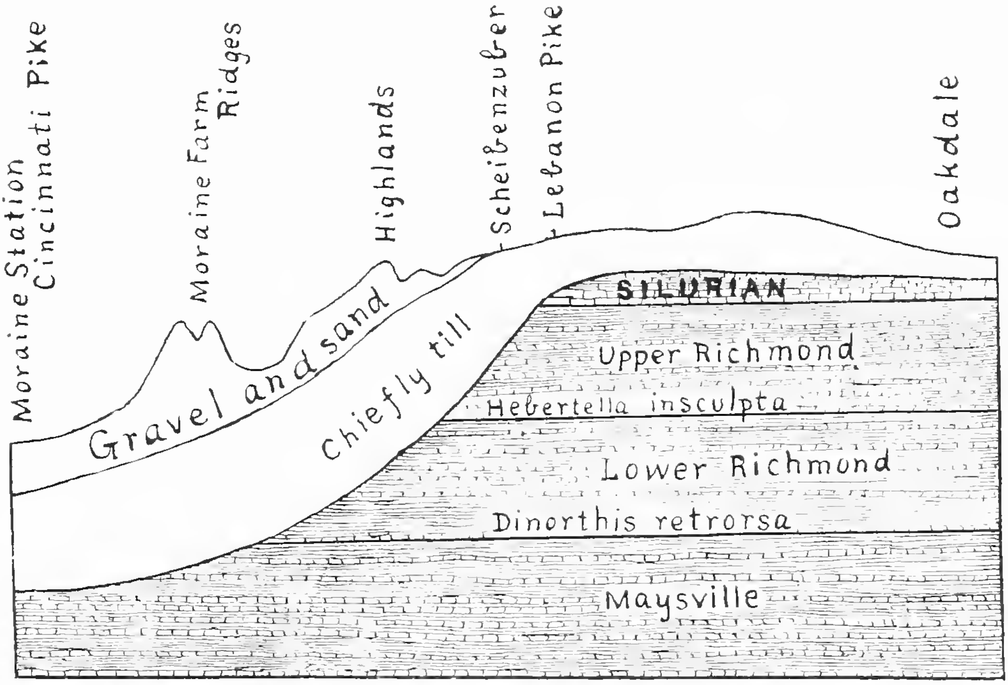
As a rule, the subglacial streams found their exits somewhere within the limits of the preglacial valleys, and the gravel and sand deposits which they heaped up rarely rise much above the level of the high hill land bordering the valley. For instance, the greatest area of sand and gravel in the vicinity of Dayton occurs in the area south of Dayton, from Carrmonte and the Calvary cemetery southward through the Hills and Dales, and the Delco Dell as far as Hole's creek. This is an area 5 miles long and 2 miles wide within which the top of the gravel ridges often rise 100 feet above the level of the flat bottom lands, and within which the total thickness of the drift, down to the solid rock beneath, must equal locally at least 300 feet. The highest part of the gravel area west of the Cincinnati pike lies within the Calvary cemetery and is 940 feet above sea level. The highest part of the Adirondack ridge in the Hills and Dales area is about 925 feet, rising to 940 feet toward its junction with the Panorama ridge. The highest part of the ridge area on the Moraine farm also is about 940 feet above sea level. Within the Delco Dell grounds, none of the land rises above the 925-foot level, and this is the highest level within the gravel area southward, as far as Hole's creek. A considerable part of the land along the Lebanon pike, however, lies above the 1,000-foot level, and this part is covered by gravel along its extreme western border. Farther eastward, the deposit overlying the solid rock consists chiefly of till.

Thick deposits of sand and gravel occur in the hill area south of the Xenia traction line, between Shakertown and Alpha, but the tops of these gravel deposits rarely reach 1,020 feet, while this level is attained by a considerable part of the till-covered area a mile south of the northern margin of the gravel area. Gravel and sand is abundant in the hill area south of Fairfield and of the Wright aviation field, but these gravel hills nowhere rise conspicuously above the level of the till-covered area southeast of New Germany. Enormous deposits of gravel and sand occur also along the valleys of Honey and Indian creeks, between Tippecanoe and New Carlisle, but the tops of the gravel hills rarely exceed 900 feet, while this altitude is reached by a considerable part of the till-covered area both north and south of the gravel area. Similar remarks might be made about the gravel areas east of Ginghamsburg and Chambersburg, on the western side of the Miami river; along the valley of Brush creek, 2 miles east of West Milton; and along the northern side of Wolf creek, southeast of Brookville.

89. Thick Deposits of Till

The deposits of till also appear to be thickest within the limits of preglacial valleys. At the bend of Twin creek, one mile southeast of Germantown, the exposed thickness of till equals 70 feet. At its bottom it rests upon a peaty layer containing cedar berries, fragments of wood, mosses, grasses, and sedges. At the Pinnacles, a mile northwest of Alexandersville, the total thickness of the till is at least 100 feet and probably equals 120 feet. Considerable thicknesses of till occur along the valley of Hole's creek, about 2 miles east of Alexandersville. At the Doctor Scheibenzuber farm, a mile northeast of Delco Dell, a well passed through 180 feet of till without reaching the rock beneath. At a well bored at Delco

Dell at least 120 feet of till was found beneath 75 feet of sand and gravel, without striking the underlying rock. Within the areas covered by the various terminal moraines the thickness of the till frequently exceeds 20 feet and sometimes equals 50 feet, but usually the thickest deposits of till appear to occur there where the glacial ice sheet passed from a high level area into a deep, wide valley, or where, on leaving a wide valley, it pushed up against a steep hill area.



Vertical section across the Dr. Scheibenzuber farm in an east and west direction, with a diagrammatic representation of till plastered against the eastern border of the pre-glacial valley by the southeastward moving glacial ice. At the Dr. Scheibenzuber farm a well penetrated 180 feet of till without striking solid rock. A short distance westward, gravels and sand overlap the till deposits and are well exposed along the valley southwest of the house.

In general, the glacial ice sheet appears to have moved southward without any great regard to the topography of the underlying country. It not only filled the valleys, but rose for hundreds of feet above the surrounding hills. While, in a general way, the ice may have moved downward on reaching a valley, and upward on ascending the opposite slopes, it is possible that to a large extent the upper part of the mass of ice, above the hill level, moved much faster than the lower part which was held back within the valley, and even may have sheared more or less across the latter. This may account for the slight deflection produced by valleys on the direction of the glacial striæ. It must be remembered that, aside from the valleys, the general topography of the hill lands around Dayton is comparatively flat, the hills rising in all directions to about the same general altitude. Hence the sky line as seen from any tall building in every direction around Dayton appears comparatively straight, and not deeply indented by hills and valleys. Seen from any considerable distance, the individual hills can no longer be distinguished and the individual hill summits appear to coalesce into a long, single, horizontal line. In other words, this part of southwestern Ohio may be regarded as an extensive plain deeply cut into by numerous rivers and streams. The motion of the ice across this plain was not greatly influenced by the valleys indenting the latter.

90. Many Boulders of Canadian Origin Are Without Glacial Scratches.

The first thing to attract attention at the Moraine Park station, in addition to the beautiful natural surroundings, is the pretty waiting-room. Here numerous boulders of Canadian origin have been collected from the fields and used to produce irregular color effects in the outer walls of the building. Canadian boulders are used also for the protecting walls lining the stream channel southeast of the station, and for the chimney attached to the Deeds cottage, at the extreme northern end of the Delco Dell grounds. All of the supporting walls of Ridgeleigh Terrace are constructed of similar boulders.

Comparatively few of these boulders show flattened faces or parallel glacial striæ, although many of them are strongly rounded. Most of these boulders, during their journeys southward, apparently were subjected to the rounding action of flowing water, at least during the final stages of their progress. During by far the greater part of their journey from their original Canadian homes, many of these boulders probably were transported embedded within the glacial ice, rather than pushed along at its bottom. In fact, if the boulders had been pushed along to any considerable extent at the bottom of the ice, flattened faces and glacial striæ should be in evidence more frequently, notwithstanding the later subjection of many of these boulders to the effects of running water.

91. Boulder Belts

Evidently, the boulders at one time were very numerous. At some localities they were very much more numerous than at others. They were especially numerous along the outer border of the Eaton moraine. Formerly they were very abundant along the Troy pike, south of Chambersburg, but many have been removed since, for building purposes. They were abundant in parts of Dayton View, south of Liberty, near West Alexandria, and north of Eaton. In a north and south direction, across the Eaton moraine, the boulders were scattered over an area 2 to 3 miles in width. The east and west roads crossing this moraine often encountered numerous boulders for a distance of 4 or 5 miles. So numerous were the boulders, that the Eaton moraine was known as a boulder belt. In 1878, Professor Edward Orton recorded that near West Alexandria, on the farm of David Potterf, he had counted 1,200 boulders exceeding 2 feet in diameter to the acre, and stated that there were points where boulders were more numerous than this.

Boulders are numerous also along many of the other moraines, but those along the Eaton moraine compared in numbers with any known in the Mississippi valley. They occur not only on the surface, but also enclosed within the underlying clays and gravels. Comparatively few occur more than 5 or 10 feet below the surface, suggesting that the boulders were carried along within the ice until they reached the terminal parts of the ice sheet, where they were dropped by the melting of the ice. Apparently many of these boulders were carried so far above the base of the ice sheet that they suffered less from rubbing than the main mass of rock fragments carried along in the basal parts of the ice.

92. High Points in Southwestern Ohio, Especially in the Vicinity of Dayton

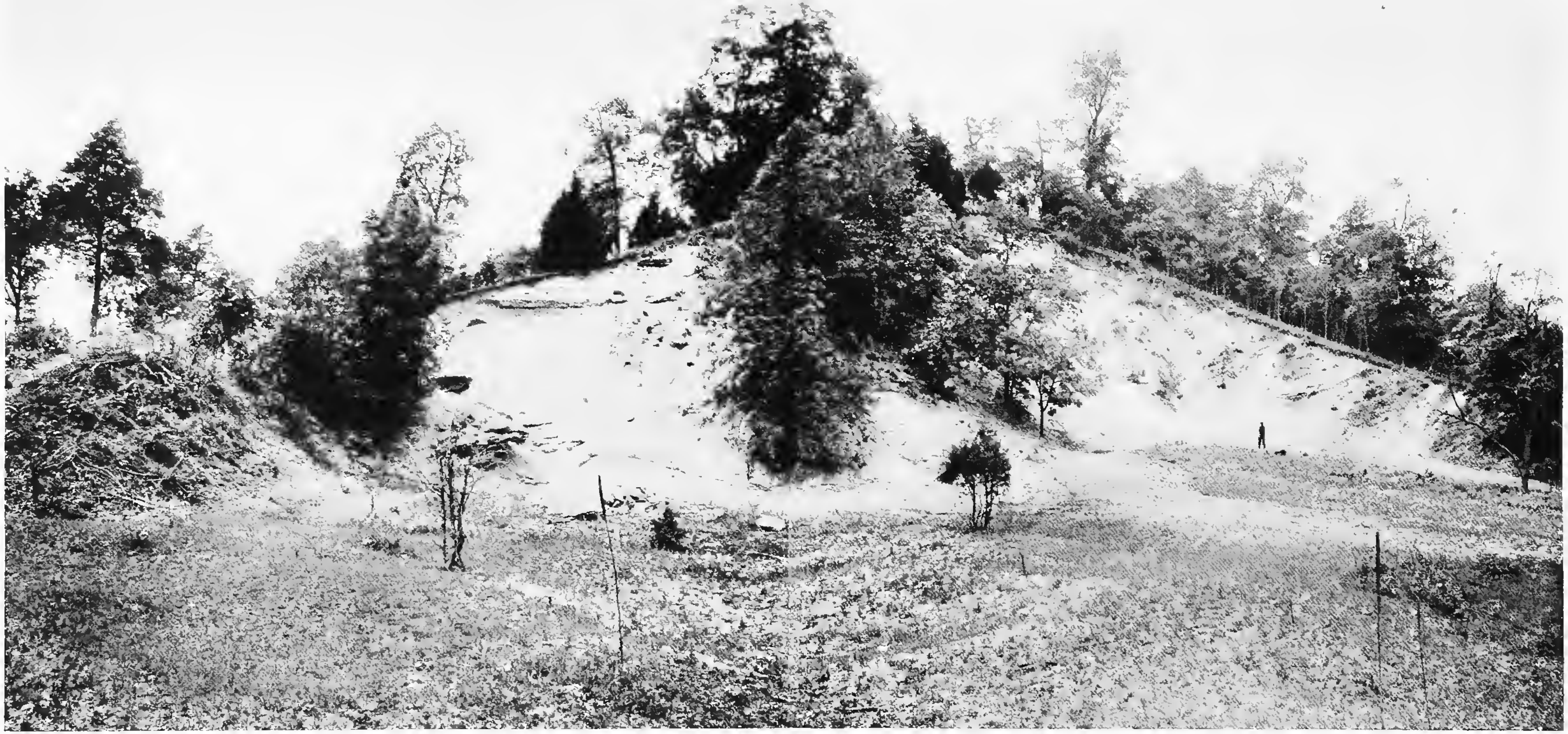
The highest land in the state of Ohio is located about 50 miles northeast of Dayton, a few miles east of Bellefontaine. Here the highest altitude is 1,540 feet above sea level. High land is found also farther eastward, in Richland, Tuscarawas and Columbiana counties, but in no case does this land attain an elevation of 1,500 feet. The highest land southeast of Dayton occurs in the eastern part of Highland county, 55 miles away. Here several high hills or mountains are located, one of which reaches an altitude of 1,300 feet.

The highest land within 15 miles of Dayton is located southeast of the David church, on the eastern side of the Lebanon pike, and about 2 miles southeast of Delco Dell. Here the highest elevation is a few feet above 1,100 feet above sea level. The highest land northeast of Dayton is located about a mile southeast of West Charleston, and is 1,022 feet above sea level. Northwest of Dayton the highest land is located about 3 miles west of Brookville, and attains a level of 1,070 feet. Southwest of Dayton, the highest land occurs about five and a half miles west of Germantown, where it reaches a level of 1,030 feet above sea.

The elevation of the base of the lamp post at the southern end of the Main street bridge is 755 feet above sea level. The average elevation of the land within the central part of the city is 740 feet. The cottages at Delco Dell are 160 feet above this level, and are freely exposed to the breezes from almost any direction. It is an ideal location in hot summer weather. The highest land in the southeastern corner of the Hills and Dales area is 40 feet higher, but is less abruptly elevated above the surrounding country.

The highest land north of Dayton occurs at the gravel pit west of the northern end of Catalpa drive, where an elevation of 1,020 feet is attained. The highest land west of Dayton, 1,000 feet above sea level, occurs west of Drexel park. The highest elevations in the eastern part of Dayton occur immediately north of the "Culebra Cut" on Huffman hill, where a height of 940 feet is reached. Fort McKinley and Oakwood have equally favorable locations, as far as elevation is concerned.

It is evident that as the city of Dayton expands its growth must be chiefly toward the surrounding hills, since the lower lands already are largely occupied. Within a short time Dayton will become a city of numerous suburbs, demanding water supplies at considerable elevations above the central parts of the community. Then the great quantities of water in the gravels east of Dayton will be of increased importance, and it will be necessary to draw upon the supplies included in the territory beyond the hills east of Harshman. Only the geologist is likely to appreciate the great contribution made by glacial streams to our present and future prosperity by producing such enormous gravel deposits over the preglacial valley bottoms.



GRAVEL PIT at southern end of Schumacker ridge. Note the narrow top of the ridge and the steeply sloping sides. On the left side, the horizontal bedding may be detected, even at a distance.

View from the southern end of the Schumacker ridge, toward the till-covered hillsides on the southern side of the Kohl branch of Hole's creek. Till covers the hillsides southwestward as far as Miamisburg.

CHAPTER XIII

THE FOSSILS OF SOUTHWESTERN OHIO

93. The Number of Species Found in the Rocks of Southwestern Ohio

The animals whose remains are found in the rocks of southwestern Ohio are all sea animals. No remains of animals living in fresh-water lakes or rivers have been detected in these rocks. Only a few problematic plant remains have been detected and these also are such as belong to marine waters.

The total number of kinds or species known is very great and it is certain that the total number so far discovered forms a small part of the life which in ancient times occupied the seas which at that time covered southwestern Ohio and adjacent areas. Hitherto unknown species are being found frequently within the areas here under discussion, and it is certain the total number known will eventually be greatly increased. Moreover, there must have been an enormous number of animals whose bodies did not contain any parts hard enough to resist decay and of whose former existence we can never hope to find any evidence in the form of fossils.

Fully a thousand species of fossil animals are known at present from the blue limestones of southwestern Ohio. Included in this series of rocks are all the strata from the lower part of the Cynthiana group, along the Ohio river, to the top of the Richmond group, just below the quarry level at the Soldiers' Home, west of Dayton. Of this list of 1,000 species, 400 are known in the Richmond group alone. Since all of this group occurs within the limits of Montgomery county it is certain that diligent search here eventually would result in the discovery of almost all of the species known from the Richmond group. Indeed, Waynesville, a short distance beyond the southeastern corner of the county, is known throughout the world as a great fossil collecting center, on account of the numerous new species discovered in the Richmond strata exposed in its vicinity. This does not mean that more species exist here than elsewhere, but that a larger amount of intelligent collecting was done here. The banker Harris, whose magnificent collection now is the pride of the National museum at Washington, devoted the best part of his life to his collection, and made it possible for several other collectors to do the same.

The Brassfield limestone, exposed in the quarries at Soldiers' Home and at Centerville, formerly was incorrectly identified with the Clinton of New York. From this Brassfield limestone 150 species of fossils have been identified so far. From the overlying Niagaran strata, including in this term all strata from the Dayton limestone, immediately overlying the Brassfield, to the top of the Cedarville limestone, 200 species are known.

94. The Variety of Forms of Life Found Fossil in the Rocks

To adequately represent all of this fossil life would require a large volume. To illustrate none of it would be to omit one of the most interesting details of geological information in our vicinity. To make an adequate selection among so much material presents its difficulties. Hence only two things here are attempted. The first is to give some idea of the diversity of the fossil life formerly in existence. The second is to suggest how rocks from a particular horizon may be identified by illustrating a few of those species whose vertical range appears restricted to definite divisions of rocks and whose presence therefore is regarded as proof of the presence of these divisions.

Corals are represented by figures 6, 8, and 9. Of these the horn coral, Streptelasma rusticum (Fig. 9), is common around Dayton and often is mistaken by the ignorant for small cow's horns. The honey-comb coral, Columnaria alveata (Fig. 8), is scarce here although common in southern Indiana, near Madison. Forms having the same general appearance, but belonging to an entirely different genus, occur in the Brassfield and overlying limestones. The encrusting coral, Protarea richmondensis, is of interest chiefly because it is found attached to various species of shells in the form of a thin layer. It is common in the vicinity of Dayton.

Crinoids are represented by figure 30. This was an animal which attached itself to the sea bottom by means of a long stem. Its body was covered with small plates and its arms, extending upward, were used to produce currents of water bringing food toward the mouth, which was located at the top of the body, among the arms. Locally crinoids probably were common, but on death the plates, forming that part of the animal which could be preserved as a fossil, usually fell apart so that well preserved specimens of the entire animal are comparatively rare. The specimen figured is called Cupulocrinus polydactylus. Starfish are represented by figure 4, Promopalaeaster speciosus. Only a fragment was found, the missing parts being indicated by the shading. A peculiar form of ancient sea life is represented by figure 1. This is the Agelacrinus pileus, which attached itself to shells and other smooth surfaces. The figure is very much enlarged, the actual specimen being only half an inch in diameter.

Bryozoans are represented by figure 4. Bryozoans of this type are regarded by the ignorant as roots or branches of plants. Careful examination, however, will reveal on the surface of these supposed roots or branches numerous very small pits, each of which formerly was occupied by an individual animal. In other words, the whole organism is made up of a colony of animals originating from a single individual and passing through life inseparable, very much as in the case of the compound coral illustrated by figure 8. The bryozoan here figured is Hallopora nodulosa. Bryozoans often grow to much larger size and not all of them are branched. Some of them grow into flat or nodular shapes.

The peculiar shells known as brachiopods were very common in ancient sea life. They always consist of two separable parts known as valves, and usually they were attached permanently by a short stem or pedicel to some object on the sea-bottom. Usually this pedicel left the interior of the shell by some aperture or notch which can be readily identified, and the valve bearing this aperture or notch is called the pedicel valve, while the opposite valve is called the brachial valve. The characteristic feature of these brachiopod shells, by means of which they can be distinguished from other shells, is their bilateral symmetry. In other words, if a line be drawn vertical down the middle of either valve, the parts on the right and left of this line are alike in shape and ornamentation. The following figures illustrate brachiopods: 5, 7, 10, 11, 12, 14, 15, 19, 20, 21, 22, 23, 24, 26, 28, 29 and 31.

The general group of clam shells is represented by figures 18, 25 and 33. As a rule, the two valves are alike in form, but opposite ends of the same valve differ in outline and sometimes also in ornamentation. The shell represented by figure 25 had some of the habits of the modern scallop. It rested flat upon that one of the valves not illustrated here, and this valve became flat and lost its ornamentation. The other valve is seen frequently in the vicinity of Dayton.

Snail shells are represented by figures 13 (Cyclonema humerosum) and 16 (Diaphorostoma trigonostoma). The first species is common along the railroad opposite the Franklin Chautauqua grounds. The second is not rare in the quarries southwest of Springfield.

Orthoceras fosteri (Fig. 27) is a peculiar shell looking like a thick rod, becoming gradually narrower toward one end. Usually only the cast of the interior is found, and this resembles a series of round discs, each disc being curved in a concave direction toward the larger end of the specimen and convex on the other side. These discs represent chambers within the shell. If the entire specimen had been present there would have been evidence of a single, very much longer chamber at the larger end of the specimen, which formerly was occupied by the animal itself. The series of small chambers probably was useful in making the animal more buoyant while swimming. Its nearest modern representative is the Pearly Nautilus. Even in ancient days some of the related forms of life were coiled as in the Nautilus, but many species were straight, as in the specimen illustrated. The straight forms represent the earlier types of this group of animals. Badly weathered specimens are sometimes mistaken for fossil snakes, and one found in the Soldiers' Home quarry was labeled for a long time as the backbone of a child. This is no worse than regarding the head and teeth of fossil elephants as remains of giant men, as was done in former centuries, in various parts of Europe, before there was a science of fossils.

Worms, as a rule, present bodies too soft to be preserved in the form of fossils. Nevertheless certain very small black teeth found in some of the rocks of southwestern Ohio have been regarded as the teeth of worms. Figure 24 (Lumbriconereites austini) represents one of these teeth, greatly enlarged, found just beneath the Brassfield limestone north of Wilmington, Ohio. Similar teeth have been found west of the railroad track northeast of Cowlesville, several miles north of Tippecanoe. The specimen here figured was scarcely a tenth of an inch in length.

Trilobites are represented by figures 2, 3 and 17. Calymene retrorsa (Fig. 2) is the more common form in the Richmond group near Dayton. In the underlying Maysville strata there is a larger form with more acute corners at the rear lateral angles of the head (Calymene meeki), abundant near Cincinnati. Both forms usually are found rolled up, with the head in contact with the tail, and in this form the fossil formerly was worn as a watch charm. Ceraurus miseneri (Fig. 3) also was found in a rolled-up condition, at Richmond, in Indiana. The species occurs also at the trestle crossed by the Springfield traction road, east of Dayton. Why Calymene niagarensis (Fig. 17) occurs so frequently in the form of spread-out specimens is not known. It is common in the Springfield and Cedarville limestones of southwestern Ohio.

It is evident that these fossils represent quite a considerable variety of life. The complete absence of fish, newts, frogs, reptiles, birds, or ordinary hair-bearing four-footed animals should be noted. No evidence of the

View of the watershed area between the south end of the Locust farm valley and the north end of the Kohl branch watershed. The drainage of the field is distinctly indicated, even in the immediate foreground on the left. The

View of the Walden ridge, taken from the Schumacker ridge, looking westward. An abandoned barn locates the ridge. Note the pebbles in the foreground. On account of the rocks this land is best suited for crops that do not

valley, seen from the south. The line of trees and shrubs at the far left locates approximately the crest of the far distant hills belong to the Highlands, east of the Locust farm valley.

crest of the Walden ridge. A fence at the left of the barn descends the ridge and in the low ground east of the require cultivation. The rains wash away the soil and lighter pebbles, leaving the larger ones exposed.

existence of any of these occur in the rocks of southwestern Ohio, although the earliest ancestors of fish probably were already in existence elsewhere.

95. Fossils Illustrated on the Accompanying Plates, with an Indication of Their Vertical Range in the Series of Rocks Exposed in Southwestern Ohio

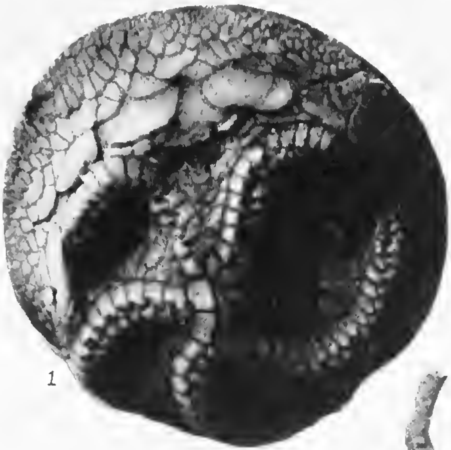
The subdivisions of which the various fossils here illustrated are characteristic, are indicated in the list of species accompanying each plate. The names of these subdivisions are given in consecutive order on page 60.

Of this list, the Eden, Maysville and Richmond groups are included in the Ordovician series of rocks, and the Brassfield, Dayton, Osgood, Springfield, Cedarville and Monroe rocks are included in the Silurian series.

The Columbus and Delaware limestones form part of the Devonian series. Various subdivisions or members of the Eden, Maysville and Richmond groups are recognized by geologists, but are not discussed here.

In descending order, these members are:

RICHMOND	Elkhorn
	Whitewater
	Salada
	Liberty
	Waynesville
	Arnheim
MAYSVILLE	Mount Auburn
	Corryville
	Bellevue
	Fairmount
	Mount Hope
EDEN	McMicken
	Southgate
	Economy
	Fulton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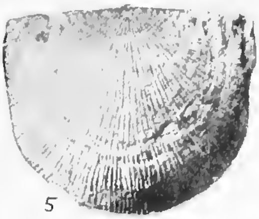
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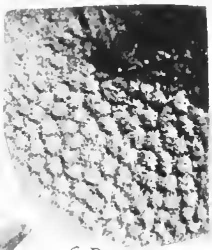
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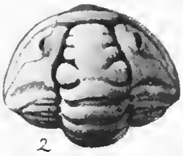
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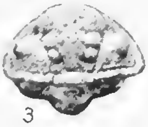
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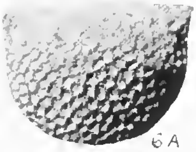
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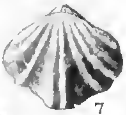
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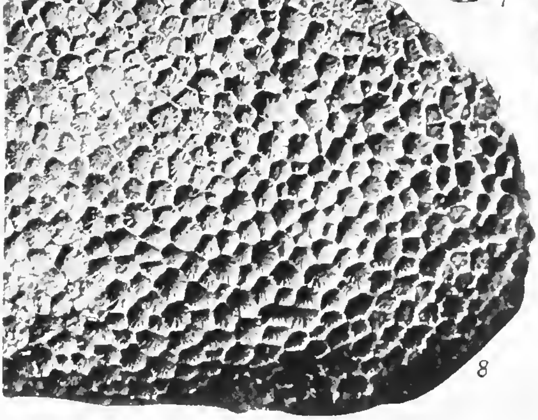
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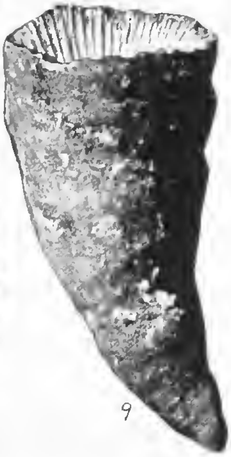
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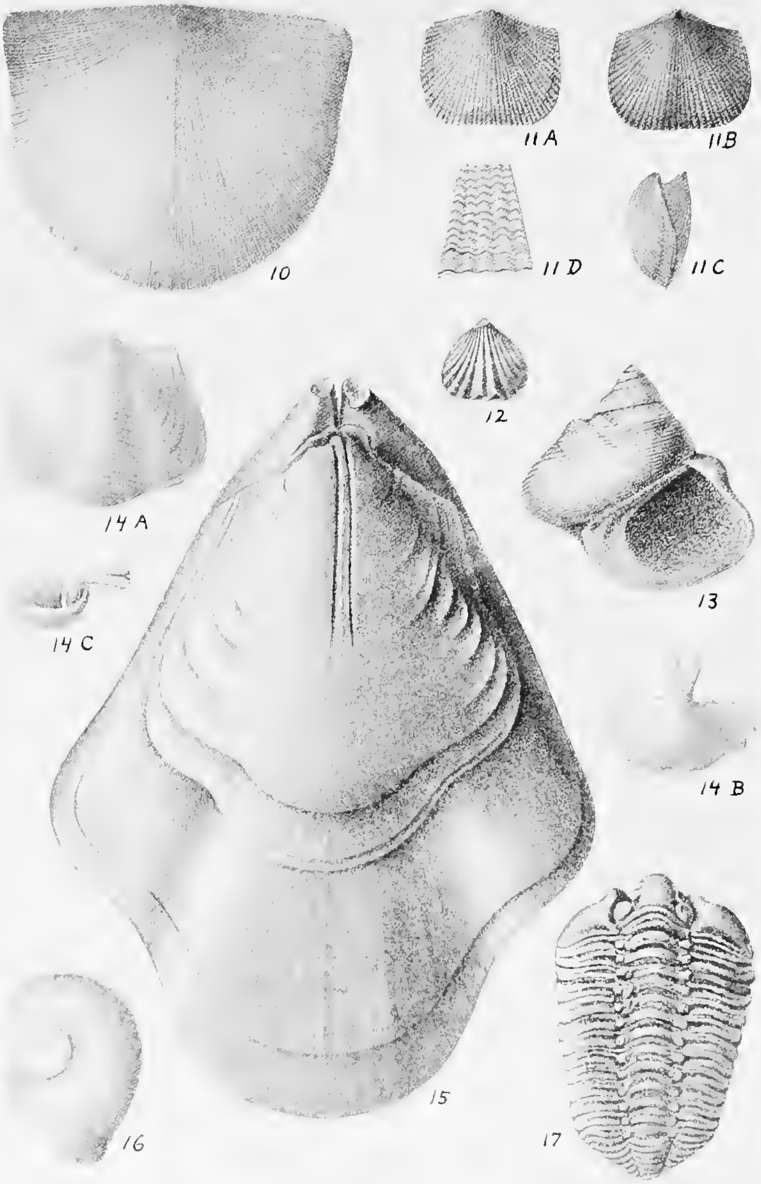
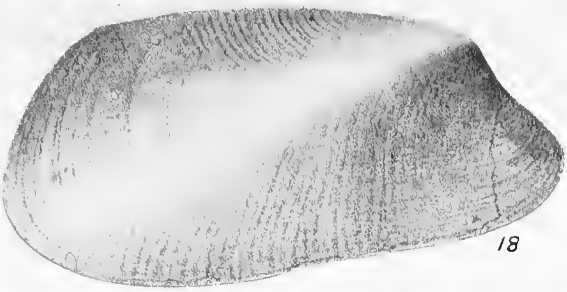
1. Agelacrinus pileus. Corryville member of Maysville group, at Cincinnati.
2. Calymene retrorsa. Waynesville member of Richmond group. The closely similar Calymene meeki is common in the Maysville at Cincinnati.
3. Ceraurus miseneri. Whitewater division of Richmond group.
4. Hallopora nodulosa. Upper division of the Eden group, at Cincinnati.
5. Strophomena vetusta. Liberty and Whitewater division of the Richmond group. An ancestral form occurs in the upper part of the Waynesville division of this group.
6. Protarea richmondensis. From upper Waynesville to top of Whitewater division of Richmond group. Figure 6B represents this species enlarged.
7. Rhynchotrema dentatum. Arnheim division of Richmond. Closely similar forms occur in the upper Waynesville and Whitewater divisions.
8. Columnaria alveolata. From upper Waynesville to Whitewater division of Richmond group.
9. Streptelasma rusticum. Waynesville to Whitewater division of Richmond group.



10. Rafinesquina alternata. From the Trenton to the top of the Richmond group. Within this range several species should be distinguished.
11. Hebertella insculpta. A, pedicel valve. B, brachial valve. C, lateral view. D, enlargement of surface, showing the characteristic transverse sharp ornamenting lines. At base of Liberty division of Richmond group and also at base of upper third of the Waynesville division.
12. Rhynchotrema dentatum. Whitewater division of Richmond. Similar forms occur also in upper Waynesville and at the middle of the Arnheim.
13. Cyclonema humerosum. Arnheim division of Richmond group, and probably also in upper part of Maysville group.
14. Triplesia ortoni. A, brachial valve. B, a fragment of the same valve showing a part that projects into the interior of the pedicel valve in such a manner as to assist in opening and closing the shell. C, a similar fragment seen from the side, and often called by children a small shovel. Brassfield limestone, at Soldiers' Home and Centerville quarries.
15. Pentamerus oblongus. Common in the Springfield division of the Silurian limestones. Found also in the Cedarville division. Rare in the Dayton limestone, immediately overlying the Brassfield limestone.
16. Diaphorostoma trigonostoma. Upper flat view presented. Seen from the side the margin is very angular. Cedarville division of the Silurian limestones.
17. Calymene niagarensis. Springfield and Cedarville limestones. The forms of Calymene found in the underlying divisions as far down as the Brassfield limestone usually are referred to the same species.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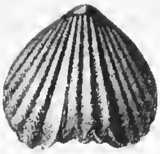
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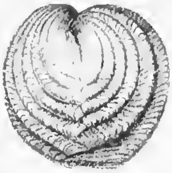
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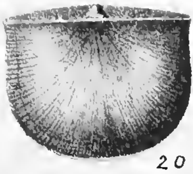
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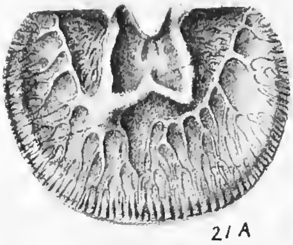
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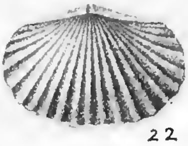
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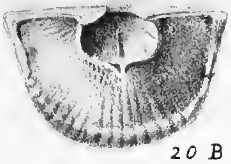
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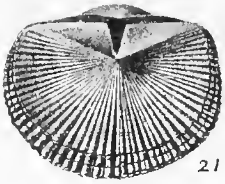
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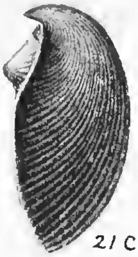
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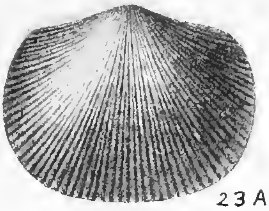
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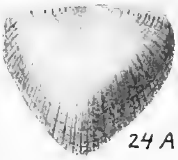
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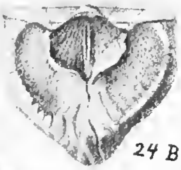
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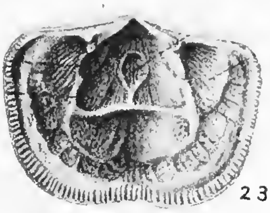
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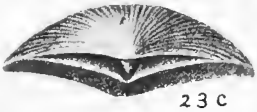
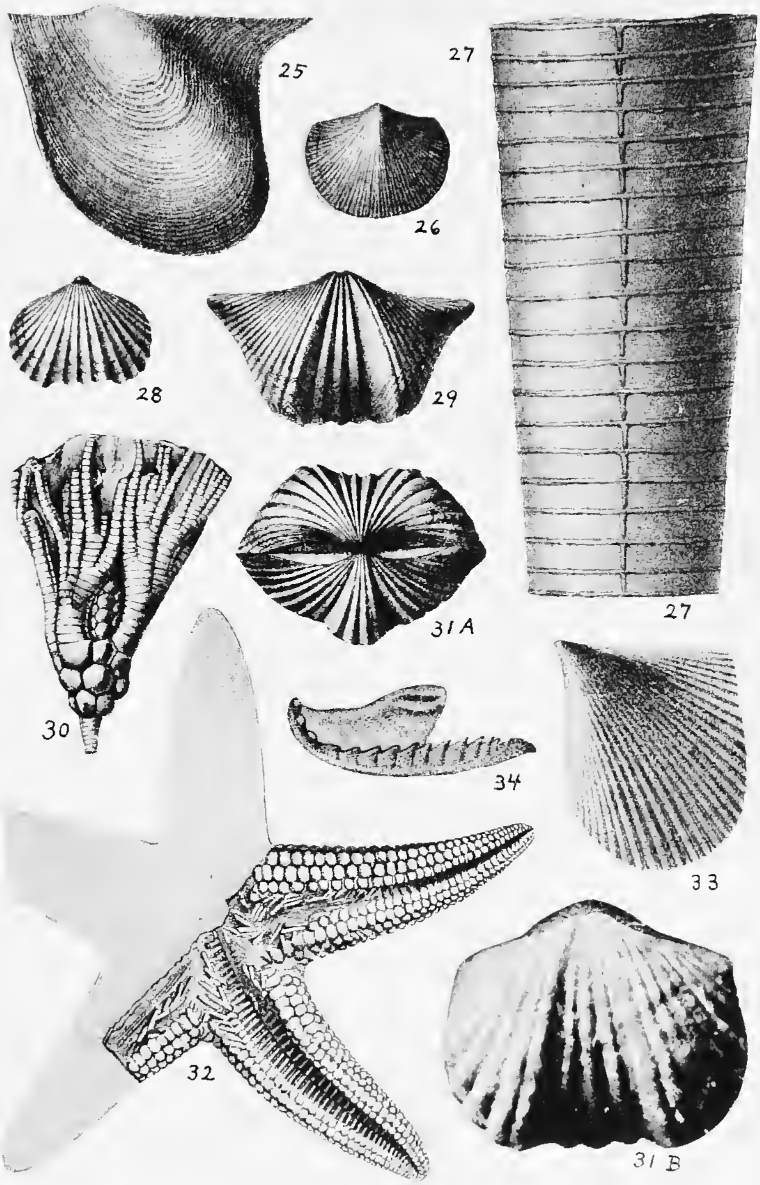
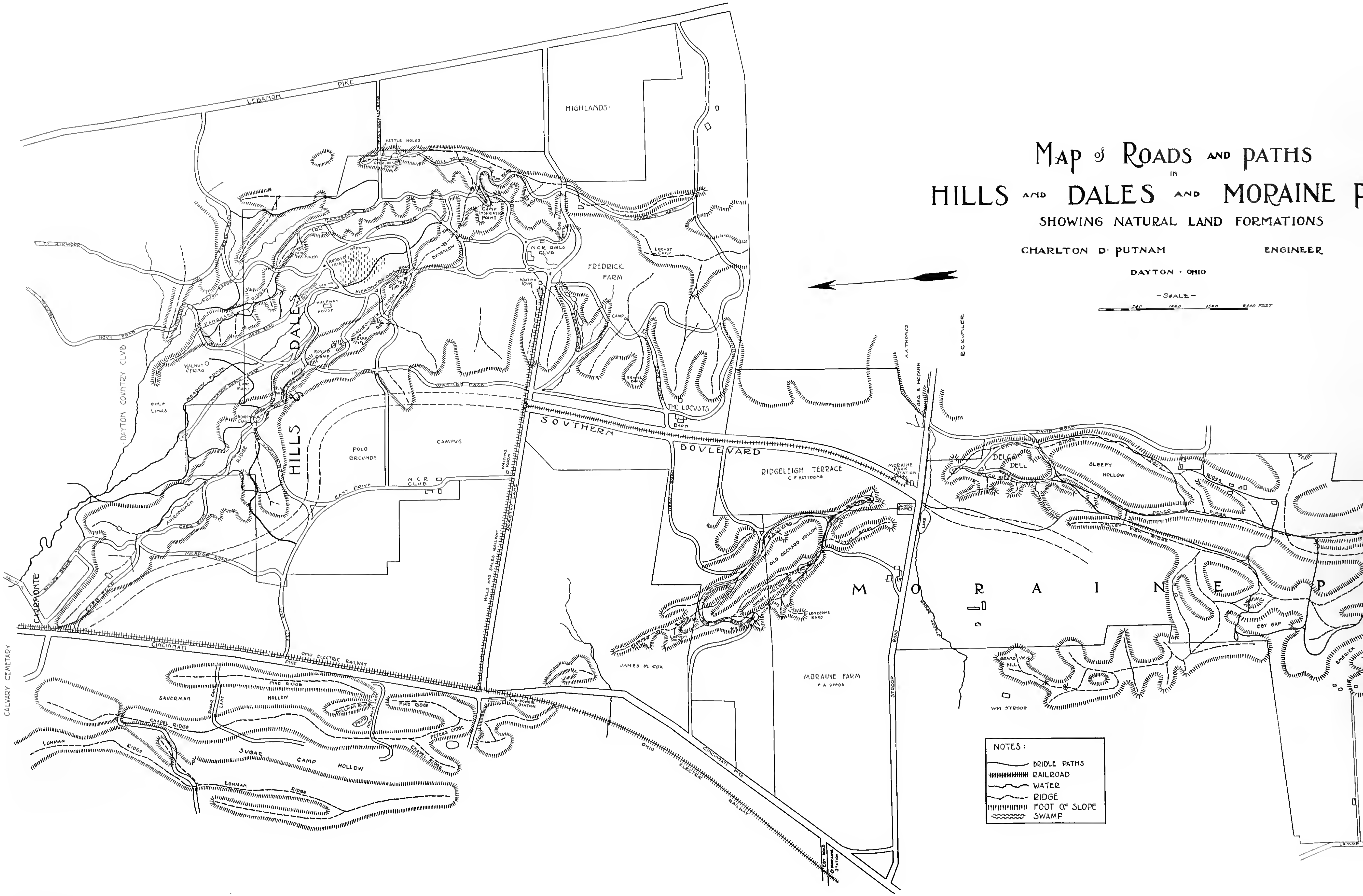

23 C

18. Pholadomorpha pholadiformis. Waynesville division of the Richmond group.
19. Rhynchotrema capax. A, the typical form, seen from the side. Whitewater division of the Richmond. B, less typical form, often compared with Rhynchotrema perlamellosa, found in the upper Waynesville and in the Liberty divisions.
20. Strophomena planumbona. A, exterior of brachial valve and top of opposite valve. B, interior of pedicel valve. Waynesville and Liberty divisions of Richmond group.
21. Dinorthis carleyi (often identified as Dinorthis retrorsa). A, interior of pedicel valve. B, exterior of pedicel valve with top of opposite valve. C, shell seen from the side. Middle of Arnheim division of Richmond group. A closely similar form occurs at the base of the upper third of the Waynesville division of the Richmond group.
22. Plectorthis plicatella. Fairmount division of the Maysville group, at Hamilton, Cincinnati, and elsewhere.
23. Dinorthis subquadrata. A, brachial valve. B, interior of pedicel valve. C, shell seen along the hinge line. Liberty and Waynesville divisions of the Richmond group.
24. Strophomena nutans. A, brachial valve. B, interior of pedicel valve. Upper third of Waynesville division of Richmond.



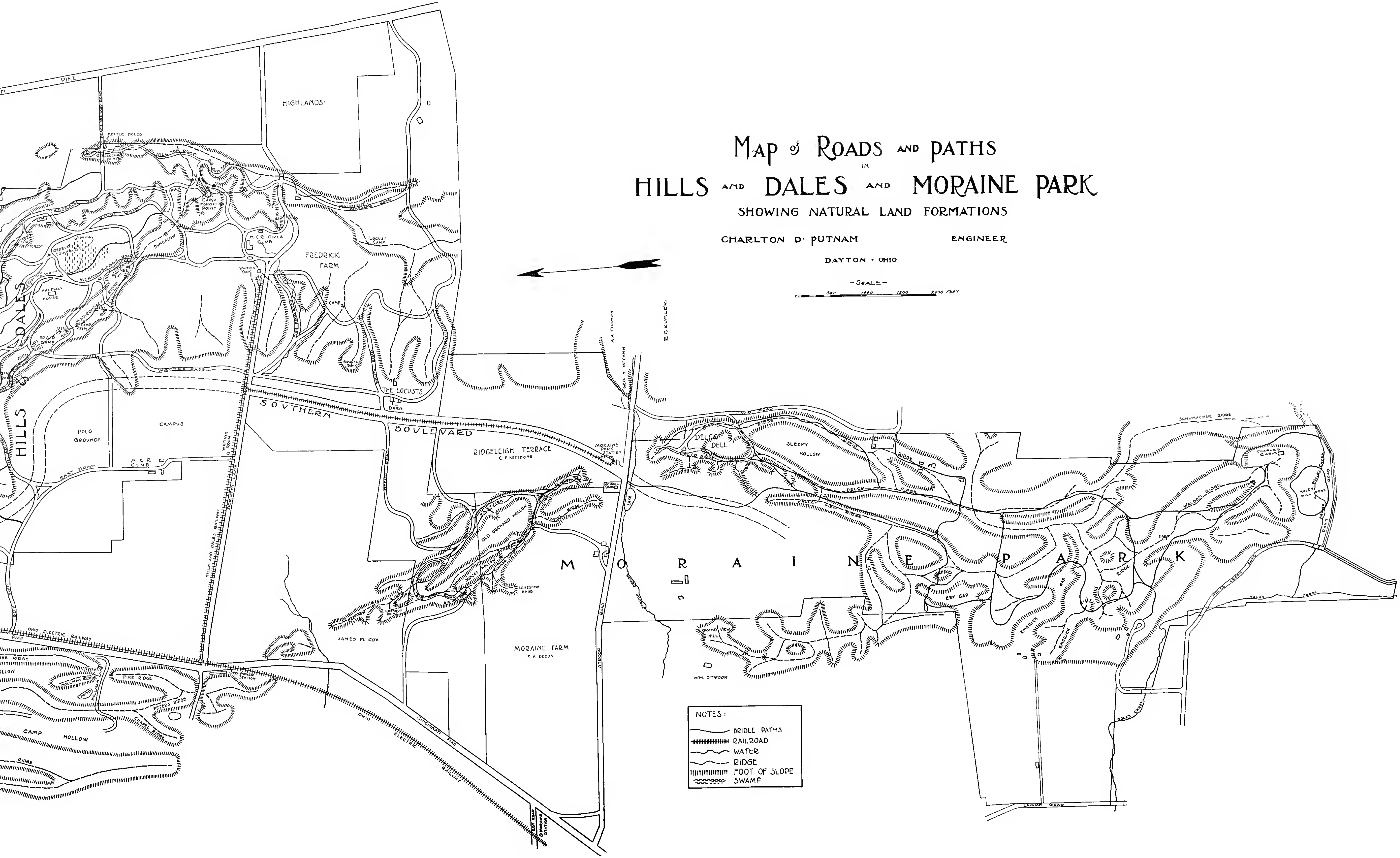
25. Pterinea demissa. Maysville and Richmond groups.
26. Dalmanella jugosa. Waynesville division of Richmond group. Similar forms occur in the Arnheim division.
27. Orthoceras fosteri. Waynesville division of the Richmond group.
28. Orthorhynchula linneyi. Cynthiana group, chiefly in Kentucky. Here this species occurs also in the upper part of the Fairmount division of the Maysville group.
29. Platystrophia acutilirata. Whitewater division of the Richmond group. Similar forms occur in the Liberty division.
30. Cupulocrinus polydactylus. Liberty division of Richmond group.
31. Platystrophia ponderosa. A, view along the hinge line. B, pedicel valve. From upper part of Fairmount to top of Mount Auburn division of Maysville group, also near middle of Arnheim division of the Richmond group.
32. Promopalaeaster speciosus. Probably Fairmount division of Maysville group at Cincinnati, Ohio.
33. Byssonychia radiata. Waynesville division of the Richmond group. The typical forms of Byssonychia radiata occur in New York state, in the Lorraine group.
34. Lumbriconereites austini. Single tooth, one tenth of an inch in length, here greatly magnified. Elkhorn division at the top of the Richmond group.



MAP OF ROADS AND PATHS
IN
HILLS AND DALES AND MORAINE P
SHOWING NATURAL LAND FORMATIONS

CHARLTON D. PUTNAM ENGINEER

DAYTON · OHIO



MAP of ROADS AND PATHS IN HILLS AND DALES AND MORAINE PARK
SHOWING NATURAL LAND FORMATIONS

CHARLTON D. PUTNAM ENGINEER

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